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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS.

W. O. ATWATER, DIRECTOR.

FARMERS' BULLETIN, No. 1.

AGRICULTURAL EXPERIMENT STATION,
FEB 7 1893
UNIVERSITY OF ILLINOIS.

THE WHAT AND WHY
OF
AGRICULTURAL EXPERIMENT STATIONS.

JUNE, 1889.

WASHINGTON:
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1889.

LETTER OF TRANSMITTAL.

DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
June 15, 1889.

SIR: I have the honor to transmit herewith, for publication, Farmers' Bulletin No. 1, of this office, containing a brief statement of the history, work, and aims of the agricultural experiment stations.

Very respectfully,

W. O. ATWATER,
Director.

Hon. J. M. RUSK,
Secretary of Agriculture.

This bulletin is intended as the first of a series, the object of which is to give information about the experiment stations and their work, by collating results bearing upon special topics and putting them into brief, clear, practical form for farmers and others to read. A series of Experiment Station Bulletins, of which the first has been published, is intended to furnish accounts of current operations of the stations, and kindred information for station workers and others interested in agricultural science. Other publications, in the hands of the printer or in preparation, will also furnish information of interest.

The experiment station enterprise rests upon the broadest considerations of the prosperity, intelligence, and virtue of our people, and on these grounds it appeals to every citizen for discriminating criticism and cordial support.

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THE WHAT AND WHY OF AGRICULTURAL EXPERIMENT STATIONS.

WHAT THE STATIONS ARE FOR.

"Farming is a perpetual trying of experiments with soils, manures, and crops; with cattle and cattle food; with milk, butter, and cheese; with plows, harrows, and harvesters; with an almost endless list of things. The most successful farmers—those who get the most out of their land, their cattle, their crops, their fertilizers, their implements, and their labor—are those who experiment themselves most industriously, most skillfully, and most intelligently, and who take the fullest advantage of the experiments of others. The best agriculture is that which, in old countries, on worn and intractable soils, has learned by long-continued and varied experiment to make the gain of farming sure."

Once the farmer made the rude tools he needed for the primitive practice of his art. Now he employs implements and machinery which can be made only with large capital and the highest mechanical skill, and by men who make this manufacturing a business. So the experiments which he can make do not meet his needs to-day. Research, the finding out of nature's secrets, the discovery of the laws which underlie the right practice of agriculture is costly. The more useful it is to be the greater must be the outlay of money, labor, and scientific skill. Here, if anywhere, wise economy calls for the best.

Within recent times farmers and men of science interested in farming have seen the advantage of using the resources of science to improve the practice of agriculture and have established agricultural experiment stations.

The object of these stations is to experiment and to teach, "to make a regular business of discovery for the use of farming," "to promote agriculture by scientific investigation and experiment," and to diffuse as well as increase the knowledge which improves farm practice and elevates farm life.

Established for the benefit of agriculture and hence of the community at large, the most of them connected with educational institutions where experience shows their work is most successfully done, these stations seek answers to the questions which agricultural practice is asking as to the tillage of the soil; the nature and action of manures;

the culture of crops; the food and nutrition of domestic animals and of man; the production of milk, butter, and cheese; the diseases of plants and animals; and, in general, whatever the agriculturist needs to know and experimental science can discover.

But farmers have asked and have received from the stations more than the help to improve their crops and their cattle and to make more money. They have felt the need of something higher and better for themselves, their wives, their children, their homes, and their profession. In the isolation and the day-by-day struggle of farm life the opportunity for intellectual culture is all too small. Modern science reveals operations of nature in their truth and beauty, and lifts us, by their contemplation, out of ourselves to higher things. It finds as much that is wonderful in the growth of a blade of grass as in the motions of the planets, as much of inspiration in the process by which a clod of earth gives up its fertility as in the forces that keep the stars in their places in the universe. It shows us how the things we have to deal with in our homeliest toil connect us, if we but understand the linking, to what is most elevating in man's thought and hope. It helps supply that food for the mind without which we starve in drudgery, but by the strength of which we rise to a higher plane of life. It is for the acquiring and diffusing of such knowledge, which is explained in books, popularized in lectures, and disseminated in the columns of the best papers; which interests the home circle, and supplies themes for farmers' institutes and conventions; which helps farmers to improve their business and increase their incomes while it elevates farming as a profession and—what is by no means the least of its benefits—shows the boys that it is a profession in which brains can be used with profit; it is for this as well as for their help to farm practice that experiment stations are established and their workers are laboring with so much enthusiasm.

WHAT THE STATIONS DO.

The stations make experiments in the laboratory, the greenhouse, the garden, the orchard, the field, the stable and the dairy. It is doubtless safe to say that there are few subjects which the farmer has to deal with in the tillage of the soil, the saving and use of manures, the cultivation of his crops, the care of his stock, the management of his dairy, and the preservation of his crops or stock from insect pests and from diseases, that are not being studied, directly or indirectly, by one or more agricultural experiment stations.

The space here allows only a single illustration of the methods and spirit of experiment station work. Suppose the question to be one of feeding. What are the effects of differents kinds of fodder, as hay, corn meal or bran, fed to cows, upon the quantity or quality of the milk? Or, what feed shall we use to make better pork at less cost? Or, what are the most economical rations for fattening steers or working horses? To get answers to these questions the stations make actual tests by feeding the animals and noting the results. These tests differ from ordinary farm experiments in that they are more elaborate and accurate, in other words, more scientific.

Successful feeding is not merely a matter of so much hay or corn or turnips, but of the nutritive ingredients which they contain and which the animal digests and uses to make blood, bone, muscle, fat, or milk, or uses as fuel to keep it warm and give it strength for work. The chemist of the station, with the apparatus of his laboratory, analyzes the material fed; that is to say, he separates the food into its constituent parts and finds just how much of each nutritive substance the animal consumes. Sometimes the excrement, the undigested portion, is also weighed and analyzed, so that by comparing this with the food he learns how much of the whole food and of each ingredient the animal actually digests. In experiments with milch cows the milk is likewise weighed and analyzed, and sometimes the cream is churned to see how much butter it will make. In some experiments even the air the animals inhale and exhale is measured and analyzed with the aid of very elaborate apparatus. When the feeding trial is done, the animal is sometimes slaughtered and the different portions likewise weighed and analyzed. By such means the effects of different kinds of fodder and methods of feeding and treatment are learned. A single experiment often requires the labor of several men for weeks or months. The same experiment has to be repeated again and again with different animals under different conditions. So much does it cost to get reliable answers to the seemingly simple questions which farmers ask.

A recent editorial in a leading live-stock journal says:

> By the feeding trials already conducted, especially with young animals, it has been demonstrated that different feeds modify the relative proportion of the different organs of the body; that the blood can be increased or diminished; the liver made larger or smaller; the muscular system increased or decreased in proportion to the rest of the body * * * [even the bones can be made weaker or stronger]. These marked differences in results are not produced either by over or under feeding, but by the difference in the chemical constituents of the ration. Here is a side of live-stock management that is practically new to us, and its development must be of the highest importance.

It is an old saying that "the best part of the breed goes in at the mouth," but it has been reserved for the experiment stations to show how and why this is so, to give the scientific explanation of the maxim, and to put stock-feeding upon a more rational, that is to say, a more profitable, basis. And they are studying in like manner, and with like results, the other important problems upon which the future progress of our agriculture depends.

ORIGIN AND DEVELOPMENT OF THE STATIONS.

Nearly forty years ago a company of farmers joined themselves together in the little German village of Moeckern, near the city and under the influence of the University of Leipsic, called a chemist to their aid, and, with later help from Government, organized the first agricultural experiment station. Liebig in Germany, Boussingault in France, Lawes and Gilbert in England, and other great pioneers had been blazing the path of progress for years before. A great deal of research bearing upon agriculture had been and is still being carried on in the schools and universities, but the action of these Saxon agriculturists in 1851 marks the beginning of the experiment station proper—the organization of scientific research with the aid of government "as a necessary and permanent branch of agricultural business."

The seed thus sown has brought forth many fold. In 1856 there were five; in 1861, fifteen; in 1866, thirty; and to-day there are more than one hundred experiment stations and kindred institutions in the different countries of Europe. In each of these, from one to ten or more investigators are engaged in the discovery of the laws that underlie the practice of farming, and in finding how they are best applied.

So rapid and so sure has been the progress of this enterprise in both hemispheres, that private persons, educators, societies, and governments have learned the usefulness and indeed the necessity of these institutions, not for the farmer alone, but for all who are dependent upon the products of the soil. The movement is extending to Asia and to South America; everywhere, indeed, its importance is coming to be felt.

The first agricultural experiment station in America was established at Middletown, Conn., in the chemical laboratory of Wesleyan University, in 1875. The example was speedily followed elsewhere; in 1880 four were in operation, and in 1887 there were some seventeen of these institutions in fourteen States. In that year Congress made the enterprise national by an appropriation of $15,000 per annum to each of the States and Territories which have established agricultural colleges or agricultural departments of colleges. This has led to the establishment of new stations or the increased development of stations previously established under State authority, so that there are to-day forty-six, or, counting branch stations, fifty-seven agricultural experiment stations in the United States. Every State has at least one station, several have two, and one has three. Before provision had been made by the last Congress for the admission of the new States Dakota had established one within her boundaries and several other Territories are preparing to do likewise.

These forty-six stations now employ over three hundred and seventy trained men in the prosecution of experimental inquiry. The appropriation by the United States Government for the fiscal year just closing, for them and for the office of experiment stations in this Department, is $595,000; for the coming year it is $600,000. The several States appropriate about $125,000 in addition, making the sum total of about $720,000 given from public funds the present year for the support of agricultural experiment stations in the United States. This may seem like a large sum to expend annually for agricultural experiments, but it is less than 10 cents for each of the 7,500,000 farm-workers of the country, less than 2½ cents for each of the 30,000,000 of our population directly dependent upon agriculture for their support, and less than 1¼ cents for each of the 60,000,000 of our people who consume the products of our farms. The farming lands, farm implements, and live stock of the country are estimated to be worth $12,000,000,000. The experiment stations cost us, therefore, about $6.25 a year for every million dollars invested in agriculture. Or, reckoning the annual value of the products of our farms at $2,200,000,000, we are now spending about 33⅓ cents for every thousand dollars' worth of products in an attempt to increase the value of those products in future years.

THE EUROPEAN STATIONS.

Of the experiment stations and other like institutions for agricultural research in Europe, sixty-two are in Germany. These latter employ two hundred and seventeen scientific specialists. According to the best accessible accounts, twenty-seven German stations exercise control of commercial fertilizers, twenty-nine of feeding stuffs, and thirty of seeds by examination of wares in the interest of the purchaser; this, however, in most cases, being only part of the work done. Some stations follow a number of lines of inquiry, others confine themselves to one or two. In general, those have been most successful which have studied the smallest number of questions in proportion to their resources, or, to put it in another way, experience has shown the advantage of specializing. Fifteen are devoted mainly to investigations in vegetable physiology, including nutrition of plants; seven to animal physiology, including feeding experiments; three to dairy industry; four to sugar-beet and three to fruit and vine culture. Nine have buildings for vegetation experiments, four have special structures for feeding experiments with animals, and two have experimental gardens. While they conduct more or less field experiments (the first station was started on a farm), few own experimental farms, and those few make but little use of them, for the simple reason that experience has shown that, generally speaking, the things which most help farmers, outside of what they can study on their own farms, the stations can best find out in the laboratory, the greenhouse and the experimental stable. They have learned the costly but most valuable lesson that the kind of experimenting which seems on the surface the most practical is apt to prove the least useful and that it requires abstract and profound research to discover the things which the plain, ordinary farmer needs to know.

The European stations have become as firmly established as schools, and for the same reason, namely, that their value is demonstrated beyond question. A single illustration of their usefulness will suffice here. "The consummate product of applied farm-science is the Farmers' Almanac, which tens of thousands of German farmers carry in their pockets. It contains a calendar, tables of movable feasts, blanks for daily memoranda, cash accounts, and so on, such as we have in our diaries. Then follow blanks for names of workmen, their work and wages, forms for registering cows and their daily or weekly yield of milk, and for other stock; other forms for keeping account with each field on the farm—its size, crop, manure, seed, and produce, and so on. Then comes a series of tables and statements, which compress in brief space an amount of information that is almost marvelous.

"One table gives the amount of seed by weight or measure needed per Prussian acre (morgen) or hectare, broadcast or in drills or hills, for each of ninety-five different kinds of crops. Another gives what they call in Germany fair yields (they would be large yields here), with duration of germinating power of the seed, period of growth of the plants, and what corresponds in German weights and measures to weight per bushel or bulk per 100 pounds of the different kinds of produce. Further on are tables of mixtures of grass seeds for different soils and purposes, number of plants per acre, valuation of seeds, and so on.

"But the most remarkable tables are those of the chemical composition of plants, fertilizers, feeding-stuffs, fodder-rations, and human food, and even of the whole bodies of animals.

"If the farmer wishes to find how much plant-food he has removed from his field in a hay crop of 5 tons, he turns to a '*Table for calculating the exhaustion and enrichment of the soil*,' and finds that the 5 tons of hay would contain about 155 pounds of nitrogen, 132 pounds of potash, 8½ pounds of lime, 41 pounds of phosphoric acid, and so on. The composition of nearly two hundred kinds of grasses, grains, straws, root crops, etc., are given in this table. If he now wishes to calculate how much plant-food he gives back to his field with a given amount of manure he turns to another part of the table, and finds the average composition of one hundred and twenty-six kinds of manures and fertilizing materials. There are, too, clear figures and explanations to help him calculate how the analysis of a fertilizer compares with standard articles of this sort and what it is worth. From other pages he learns how to calculate how much material ought to be produced by given kinds of animals from given food, and so on.

"Not a bit less valuable are the tables of the composition of feeding-stuffs and fodder-rations. The farmer sees at a glance how many pounds of the valuable food ingredients—protein, carbohydrates, and fats—there are in hay, straw, corn-stalks, bran, cotton-seed meal, and two hundred and fifty other materials which German farmers feed to their stock. Close by is a table of feeding standards, which tells how much of each of these ingredients will make a fair daily ration per 1,000 pounds, live weight, of oxen at rest in the stall, oxen at work, milch cows, young cattle, and so on. By comparing the composition of these standards with that of the feeding stuffs in the barn or store rations can be calculated which will bring the largest amount of work or meat or milk at the least cost. Of course these rules are not to be followed blindly; experience and good judgment combined with the rules make the book useful to the farmer."

The information contained in the Almanac does not all come from the agricultural experiment stations, but a large amount of it, and that which is really most useful does come from them and would not be available without them. Nor is this all. The disposition and ability to use all this are as important as the information itself. This, too, is greatly aided by the scientific and educational work of the stations.

We want the same things in this country. Much of the fruit of foreign research and experience can be made available for our own use, but it needs working over to fit it to our needs and we must have independent investigation of our own.

WHAT THE AMERICAN STATIONS ARE DOING.

Although the first of the American stations was established less than fourteen years ago (October 1, 1875), and the majority of them have been in operation scarcely a year, they have already done a large amount of work scientifically creditable and of the largest practical value. Future publications of this office will describe what the stations are doing and explain the practical results. Only a few general statements and illustrations can be given here.

Our stations are conducting a large amount of scientific research in the laboratory and the greenhouse, and an equally large amount of practical experimenting in the field, the orchard, the stable, and the dairy. Some stations make a specialty of experiments with home-made and commercial fertilizers; others are endeavoring to show what can be done to restore the fertility to worn-out lands; others deal largely with the culture of fruit in orchards and vineyards; others are engaged on work relating to the composition of fodders and the methods of storing them; others are experimenting on the feeding of animals, and still others on diseases of animals and plants and their cure. Irrigation receives a good deal of attention in Colorado, sugar-making in Louisiana, wine-making in California. At least one station is doing something in poultry-raising, and another in the keeping of bees. Most of the stations give attention to several lines of work.

It is only the older stations from which we have a right to expect the most satisfactory results. The oldest is the Connecticut State Station. In this State the farmers are especially interested in manures and fertilizers, and in cattle-feeding and dairying. This station has naturally devoted a large share of its attention to commercial fertilizers and feeding-stuffs. The result has been that inferior materials have been driven from the markets of the State, and not only that, but the farmers have been taught much concerning the relative values of the materials they buy or produce for feeding their crops and their stock, and how to utilize them most advantageously. Besides this, and a great deal of other practical work, the station has done much to benefit other stations and the agriculture of the whole country by scientific researches relating to the methods of agricultural investigations.

When the station begun its work in 1875 a number of brands of fertilizers then being sold in the State were analyzed and their composition compared with the selling price. It appeared that, at the rate farmers were paying, the nitrogen cost from 10⅓ cents to $1.67, and the soluble phosphoric acid from 10¾ to 25½ cents per pound. The report of the station for 1888 shows the nitrogen in the fertilizers sold in the State in that year to cost from 12 cents to 18 cents, and the soluble phosphoric acid from 8 cents to 8½ cents. There were no fraudulent articles in the market. Connecticut farmers pay over $200,000 yearly for the phosphoric acid of commercial fertilizers. In this item alone the station saves more than its cost.

Before the establishment of the stations very few farmers in New England knew how to judge of the value of a guano or phosphate from its composition. Chemical terms were Greek to them. Of the demands of plants and the deficiencies of soils they had very little idea. Two or three years ago an advertisement of a firm of fertilizer manufacturers was circulated in Connecticut and in other States thereabouts. There was not a word in it about the remarkable increase of crops which the fertilizers would bring; there was not a single recommendation from a farmer who had put them to practical test and learned their wonderful value; but there were statements of percentages of nitrogen, of phosphoric acid, soluble, reverted, insoluble, and of potash as sulphate and chloride, which the fertilizers had been guaranteed by the manufacturers to contain, and alongside these were given the percentages which had been found in the articles as the farmers had bought them and the stations in their behalf had analyzed them. This is a firm of shrewd business men who manufacture and sell fertilizers to make money. They had found that farmers had learned something of chemistry and were buying their fertilizers on a scientific basis, and that to get the most and the best trade it would pay them to advertise and sell on that basis.

At a meeting of the Connecticut State board of agriculture, in December, 1888, one day was devoted to the experiment stations, of which there are now two in the State. It has been the policy of the stations to institute experiments among farmers on their own farms, both for practical and for educational purposes. Some of the experimenters were present, and gave accounts of their work regarding the use of fertilizers and what they had learned from it. They talked of nitrogen, phosphoric acid, and potash; of agricultural and commercial values of fertilizing materials; of the feeding capacities of different plants; of the differences in soils; of the adaptation of fertilizers to soil and crop; of the relative merits of commercial fertilizers and farm manures as shown by the cost, composition, and effect upon quantity and quality of crop produced; of the different methods of applying manures, and of other kindred topics. Their statements were scientifically accurate, and the practical value was so plain as to be appreciated by every one who heard them. One of the station directors, a college professor, remarked that he sat through the whole discussion ready to rise and make explanations if they were called for, but found no occasion to do so, and felt as though his occupation was gone.

The men who thus united science with practice, who showed their fellow-farmers how much of pecuniary profit as well as mental satisfaction there was in all this work, earn their living on their own farms by the labor of their own hands. They had enjoyed no better education than their neighbors, but they had taken advantage of the help of the experiment station. Such men are light-houses. The value of their influence can not be estimated. Where such work is done farming will flourish. The tendency of such things is to make agriculture a profitable, elevating, and attractive profession.

The experience in other States is the same as in Connecticut. A farmer in New Jersey, who has conducted some of these experiments under the direction of the station in that State, says that the simple fact that he has learned from them "that his soil lacks potash," which is cheaply supplied by German potash salts, has already been worth $500 to him. Another farmer in the same State told the writer that the information he had got from these experiments had been worth more than $2,000 to him in a single year. And it must be borne in mind that the subject of "fertilizers" is only one of the many which the stations are working upon.

The first decade of the life of the North Carolina station, which was begun in 1877, has been devoted, for the most part, to problems relating to the control of the trade in commercial fertilizers, to the investigation of natural fertilizers (marls, phosphates, etc.), and the best methods for their use, and to the education of the farmers about farm manures and the best ways of saving, composting, mixing, and using them. Among the valuable results due directly or indirectly to this work are an increase of 14 per cent in the quality of the commercial fertilizers sold in the State, and a decrease in the number of acres devoted to cotton; the establishment of fertilizer factories and cotton-seed oil mills in the State, and the making of thousands of home-made composts by farmers in every section of the State.

The New Jersey State station was established March 18, 1880. Its work has been both scientific and practical. The analyzing of commercial fertilizers, fodders, and feeds offered in the markets of the State has been largely and regularly carried on, with important results in securing purity of product and honesty of dealing, and in teaching the farmers of the State the real commercial and agricultural value of these fertilizers. Field experiments have been made with a large variety of barn-yard and commercial fertilizers on different crops in most of the counties of the State.

The diseases of plants, vines, and trees have been studied and remedies sought, and the station has tried to introduce new crops in sections of the State hitherto comparatively barren. The sorghum experiments for this purpose have attracted attention throughout the whole country. It is safe to say that in the scientific and practical value of its work this station is equaled by extremely few of the European stations.

The station had been steadily growing in the favor of the farmers and general public of the State, and is now regarded as an educating agency of the first importance. Farmers depend upon its work, manufacturers of fertilizers are made careful, dealers in seeds and implements seek its approval. The progress of agriculture in New Jersey is marked by larger staple crops, higher enrichment of the soil, extended cultivation of market garden products, peaches, and small fruit, and a great increase in dairying. Even from year to year the progress is plainly marked. That the station contributes much to this progress there is no room for doubt.

Louisiana has three stations, the first of which was established in October, 1885, by an association of sugar planters, and the last in April, 1888. These stations have already accomplished much useful work, including investigations of the manurial requirements of various staple crops of the State; analyses and classification of the soils of the State; analyses of all the commercial fertilizers sold in the State; experiments with forty-two varieties of cotton to determine the relative yield of lint, length of staple, and strength of fiber; and the introduction, with the aid of the United States Commissioner of Agriculture, of more than seventy varieties of sugar-cane, forty-eight of which are now cultivated in the State. Each station is the headquarters for a large agricultural association, which holds monthly meetings on the station grounds. At the North Louisiana station, at Calhoun, the farmers have raised by subscription the means to build a hall for these meetings, which are frequently attended by several hundred farmers. During the season for sugar-making the sugar experiment station, which has quite recently been moved from Kenner to Audubon Park, New Orleans, is visited by planters from all parts of the world. The average number of visitors at this station during the past season was about one hundred a day.

The influence of the Wisconsin station within the State has been very marked. Its experiments on pig feeding are favorably known throughout the whole country. The following extract from a letter from Director Henry indicates some of the other good things which the station has done and is doing:

> Years ago the station, then called the Experimental Farm, sent out the Mansury barley, which has been worth a very considerable sum to our people. Last spring, after a year's patient work, our first assistant chemist announced the completion of a method by which an ordinary dairyman, with a reasonable amount of care, can de-

termine the percentage of fat in milk or cream with about as much accuracy as the chemist by the gravimetric method. This method of determining fat is being brought into general use by dairymen and others. Last summer our chief chemist, Dr. Babcock, announced the discovery of fibrine in milk, and stated that this new compound played an important part in the raising of cream. Work at the station yet to be announced shows that this discovery is of considerable importance to dairymen, and in it we have an explanation of many of the phenomena of milk and cream.

Similarly favorable reports might be given from stations from Maine to California, and from Alabama to Michigan, wherever the experimenting has been carried on long enough to give a fair test of its value.

Americans have the credit of dropping enterprises which do not pay. It is a significant fact, therefore, that no State which has once established a station has ever abandoned it. On the other hand, the revenues which the stations derive from the States, apart from those which they receive from the National Government, have steadily risen from $2,800, with which the first station begun, to more than $125,000 in the present year.

Even if some of the newer stations have as yet brought but little fruit and some that is not well matured, we may confidently expect before many years to have institutions in all the States, which will be of the highest service to American agriculture.

One most favorable indication is the earnest desire of the managers of the stations to do the best possible work. This has been particularly manifest at the conventions of the Association of American Agricultural Colleges and Experiment Stations, in which matters of station policy have formed the principal theme of discussion. The underlying thought has uniformly been to learn to do what will best serve the interests for which the stations are established.

The experiment-station enterprise is now equipped for its great work. From its small beginning, fourteen years ago, it has grown out to the farthest limits of our land, has enlisted the best colleges and universities and the ablest investigators of the country, and secured both State and national resources for its service. It has the favor not only of leading minds in science and education but also of a great army of practical farmers, to whom it has already brought substantial benefits. As the first Secretary of Agriculture has justly said:

> Of all the scientific enterprises which the Government has undertaken, scarcely any other has impressed its value upon the people and their representatives in the State and national legislatures so speedily and so strongly as this. The rapid growth of an enterprise for elevating agriculture by the aid of science, its espousal by the United States Government, its development to its present dimensions in so short a period, and, finally, the favor with which it is received by the public at large, are a striking illustration of the appreciation on the part of the American people of the wisdom and the usefulness of calling the highest science to the aid of the arts and industries of life.
>
> The present is an auspicious time for this undertaking. "In the history of no nation before have there been such a thirst for knowledge on the part of the great masses of the people, such high and just appreciation of its value, and such wide-reaching, successful, and popular schemes for self-education; no other nation has so

large a body of farmers of high intelligence; never before has the great agricultural public been so willing and indeed so anxious to receive with respect and use with intelligence the information which science offers; never before has science had so much to give." The prospects then for this, the largest scientific enterprise in behalf of agriculture that any government has undertaken, are full of promise.

THE OFFICE OF EXPERIMENT STATIONS OF THE DEPARTMENT OF AGRICULTURE.

The number and diversity of problems to be solved in the widely separated sections of our country, the need of linking the stations together, of helping to co-ordinate their efforts, of bringing to them the fruits of accumulated experience, of assisting them in research, and of collating their products and making them available to the public whom they serve, and the evident propriety that the Department of Agriculture should aid the enterprise in these respects—all these considerations evince the wisdom of Congress in providing for a central office, as a branch of this Department, to meet the need.

The stations themselves, through the Association of American Agricultural Colleges and Experiment Stations, were the prime movers in securing the establishment of this office, and have given to it their cordial sympathy and support.

PUBLICATIONS.

The stations publish bulletins and reports of their work, which are supplemented by publications of this office. Each station sends its own publications, without expense, to residents of its State who apply for them, and the publications of this office, intended for general distribution, are likewise sent on application.

A list of the experiment stations in the United States, with locations and names of directors, may be found in the appendix to this Bulletin.

Communications intended for this office should be addressed to the *Office of Experiment Stations, Department of Agriculture, Washington, D. C.*

APPENDIX.

LIST OF AGRICULTURAL EXPERIMENT STATIONS IN THE UNITED STATES, WITH NAMES OF DIRECTORS AND ADDRESSES.†

WASHINGTON, D. C.—*U. S. Department of Agriculture.* Hon. J. M. RUSK, Secretary of Agriculture. Hon. EDWIN WILLITS, Assistant Secretary. *Office of Experiment Stations:* W. O. Atwater, Director; A. W. Harris, Assistant Director.

ALABAMA—*Auburn:* Agricultural Experiment Station of the Agricultural and Mechanical College of Alabama; J. S. Newman, Director. *Uniontown:* *Canebrake Agricultural Experiment Station; W. H. Newman, Assistant Director in charge.

ARKANSAS—*Fayetteville:* Arkansas Agricultural Experiment Station; A. E. Menke, D. Sc., Director.

CALIFORNIA—*Berkeley:* *Agricultural Experiment Station of the University of California; E. W. Hilgard, Ph. D., LL.D., Director.

COLORADO—*Fort Collins:* Agricultural Experiment Station of Colorado; Charles L. Ingersoll, M. S., Director.

CONNECTICUT—*New Haven:* The Connecticut Agricultural Experiment Station; S. W. Johnson, M. A., Director. *Storrs:* *Storrs School Agricultural Experiment Station; W. O. Atwater, Ph. D., Director.

DAKOTA—*Brookings:* Dakota Agricultural Experiment Station; Lewis McLouth, Ph. D., Director.

DELAWARE—*Newark:* The Delaware College Agricultural Experiment Station; Arthur T. Neale, Ph. D., Director.

FLORIDA—*Lake City:* Agricultural Experiment Station of Florida; J. P. DePass, Director.

GEORGIA—*Athens:* *Georgia Agricultural Experiment Station; W. L. Jones, M. D., Director.

ILLINOIS—*Champaign:* Agricultural Experiment Station of the University of Illinois; Selim H. Peabody, Ph. D., LL.D., Director.

INDIANA—*La Fayette:* Agricultural Experiment Station of Indiana; Horace E. Stockbridge, Ph. D., Director.

IOWA—*Ames:* Iowa Agricultural Experiment Station; R. P. Speer, Director.

KANSAS—*Manhattan:* Kansas Agricultural Experiment Station; E. M. Shelton, M. Sc., Director.

KENTUCKY—*Lexington:* Kentucky Agricultural Experiment Station; M. A. Scovell, M. S., Director.

LOUISIANA—*Audubon Park, New Orleans:* Sugar Experiment Station, No. 1; William C. Stubbs, Ph. D., Director. *Baton Rouge:* State Experiment Station, No. 2; William C. Stubbs, Ph. D., Director. *Calhoun:* North Louisiana Experiment Station, No. 3; William C. Stubbs, Ph. D., Director.

MAINE—*Orono:* Maine State College Agricultural Experiment Station; W. H. Jordan, M. S., Director.

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† In the cases indicated by asterisks in the list it is the desire of the stations that mail be addressed, not to the directors, but to the stations.

MARYLAND—*Agricultural College:* Maryland Agricultural Experiment Station; Henry E. Alvord, C. E., Director.

MASSACHUSETTS—*Amherst:* Massachusetts State Agricultural Experiment Station; Chas. A. Goessmann, Ph. D., Director. *Amherst*:* Hatch Experiment Station of the Massachusetts Agricultural College; Henry H. Goodell, M. A., Director.

MICHIGAN—*Agricultural College:* Experiment Station of Michigan Agricultural College; Robert C. Kedzie, M. D., Acting Director.

MINNESOTA—*St. Anthony Park:* Agricultural Experiment Station of the University of Minnesota; N. W. McLain, LL.B., Director.

MISSISSIPPI—*Agricultural College:* Mississippi Agricultural Experiment Station; S. M. Tracy, M. S., Director.

MISSOURI—*Columbia:* Missouri Agricultural College Experiment Station; J. W. Sanborn, B. S., Director.

NEBRASKA—*Lincoln:* Agricultural Experiment Station of Nebraska; Chas. E. Bessey, Ph. D., Director.

NEVADA—*Reno:* Nevada State Agricultural Station; Le Roy D. Brown, Ph. D., Director.

NEW HAMPSHIRE—*Hanover:* New Hampshire Agricultural Experiment Station; G. H. Whitcher, B. S., Director.

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NEW YORK—*Geneva:* New York Agricultural Experiment Station; Peter Collier, Ph. D., Director. *Ithaca:* Cornell University Agricultural Experiment Station; Isaac Phillips Roberts, M. Agr., Director.

NORTH CAROLINA—*Raleigh:* North Carolina Agricultural Experiment Station; H. B. Battle, Ph. D., Director.

OHIO—*Columbus:* Ohio Agricultural Experiment Station; Chas. E. Thorne, Director.

OREGON—*Corvallis:* Oregon Experiment Station; E. Grimm, B. Sc., Director.

PENNSYLVANIA—*State College:* The Pennsylvania State College Agricultural Experiment Station; H. P. Armsby, Ph. D., Director.

RHODE ISLAND—*Kingston:* Rhode Island State Agricultural Experiment Station; Chas. O. Flagg, B. S., Director *pro tempore.*

SOUTH CAROLINA—*Columbia:* South Carolina Agricultural Experiment Station; J. M. McBryde, Ph. D., LL.D., Director.

TENNESSEE—*Knoxville:* Tennessee Agricultural Experiment Station; Chas. W. Dabney, jr., Ph. D., Director.

TEXAS—*College Station:* Texas Agricultural Experiment Station; F. A. Gulley, M. Sc., Director.

VERMONT—*Burlington:* Vermont State Agricultural Experiment Station; W. W. Cooke, M. A., Director.

VIRGINIA—*Blacksburg:* Virginia Agricultural Experiment Station; William Ballard Preston, Director.

WEST VIRGINIA—*Morgantown:* West Virginia Experiment Station; John A. Myers, M. A., Director.

WISCONSIN—*Madison:* Agricultural Experiment Station of the University of Wisconsin; W. A. Henry, B. Agr., Director.

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U. S. DEPARTMENT OF AGRICULTURE.
OFFICE OF EXPERIMENT STATIONS.

FARMERS' BULLETIN No. 2.

THE WORK
OF THE
AGRICULTURAL EXPERIMENT STATIONS

AGRICULTURAL EXPERIMENT STATION,
FEB 11 1898
UNIVERSITY OF ILLINOIS.

BETTER COWS. FIBRIN IN MILK. BACTERIA IN MILK.
SILOS AND SILAGE. ALFALFA. FIELD EXPERIMENTS WITH FERTILIZERS.

THE BULLETINS OF THIS SERIES WILL BE SENT FREE ON APPLICATION.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1890.

LOCATIONS AND DIRECTORS OF THE AGRICULTURAL EXPERIMENT STATIONS.

Washington, D. C.—*U. S. Department of Agriculture:* Office of Experiment Stations.

Alabama—*Auburn:* J. S. Newman. *Uniontown:* Canebrake Station; J. S. Newman. *Athens:* North Alabama Station; C. L. Newman. *Abbeville:* Southeast Alabama Station; T. M. Watlington.

Arizona—*Tucson:* S. M. Franklin.

Arkansas—*Fayetteville:* A. E. Menke.

California—*Berkeley:* E. W. Hilgard.

Colorado—*Fort Collins:* C. L. Ingersoll.

Connecticut—*New Haven:* State Station; S. W. Johnson. *Storrs:* Storrs School Station; W. O. Atwater.

Delaware—*Newark:* A. T. Neale.

Florida—*Lake City:* J. P. De Pass.

Georgia—*Experiment:* R. J. Redding.

Illinois—*Champaign:* S. H. Peabody.

Indiana—*La Fayette:* H. E. Stockbridge.

Iowa—*Ames:* R. P. Speer.

Kansas—*Manhattan:* G. T. Fairchild.

Kentucky—*Lexington:* M. A. Scovell.

Louisiana—*Audubon Park, New Orleans:* Sugar Station. *Baton Rouge:* State Station. *Calhoun:* North Louisiana Station. W. C. Stubbs is director of the three stations.

Maine—*Orono:* W. H. Jordan.

Maryland—*Agricultural College:* H. E. Alvord.

Massachusetts—*Amherst:* State Station; C. A. Goessmann. *Amherst:* Hatch Station; H. H. Goodell.

Michigan—*Agricultural College:* O. Clute.

Minnesota—*St. Anthony Park:* N. W. McLain.

Mississippi—*Agricultural College:* S. M. Tracy.

Missouri—*Columbia:* E. D. Porter.

Nebraska—*Lincoln:* L. E. Hicks.

Nevada—*Reno:* S. A. Jones.

New Hampshire—*Hanover:* G. H. Whitcher.

New Jersey—*New Brunswick:* State and College Stations; M. E. Gates.

New Mexico—*Las Cruces:* H. Hadley.

New York—*Geneva:* State Station; P. Collier. *Ithaca:* Cornell University Station; I. P. Roberts.

North Carolina—*Raleigh:* H. B. Battle.

North Dakota—*Fargo:* S. T. Satterthwaite.

Ohio—*Columbus:* C. E. Thorne.

Oregon—*Corvallis:* E. Grimm.

Pennsylvania—*State College:* H. P. Armsby.

Rhode Island—*Kingston:* C. O. Flagg.

South Carolina—*Columbia:* J. M. McBryde.

South Dakota—*Brookings:* L. McLouth.

Tennessee—*Knoxville:* C. W. Dabney, jr.

Texas—*College Station:* F. A. Gulley.

Utah—*Logan:* J. W. Sanborn.

Vermont—*Burlington:* W. W. Cooke.

Virginia—*Blacksburg:* W. B. Preston.

West Virginia—*Morgantown:* J. A. Myers.

Wisconsin—*Madison:* W. A. Henry.

STATISTICS OF THE STATIONS.

Under the act of Congress approved March 2, 1887, which provides for a grant of $15,000 per annum to each State and Territory for the purpose, experiment stations are in operation in all the States except Montana and Washington, and in the Territories of Arizona, New Mexico, and Utah. In each of the States of Connecticut, Massachusetts, New Jersey, and New York, a separate station is maintained entirely or in part by State funds, and in Louisiana a station for sugar experiments is maintained mainly by funds contributed by sugar planters. In several States branch or substations have been established. If branch stations are not counted the total number is 50; including them the number is 66. These stations, with this office, receive, the current fiscal year, $645,000 from the National Treasury, and about $125,000 from State governments and other sources. The agricultural colleges and other institutions with which the stations are connected in many cases supply buildings, ground, apparatus, and materials for experimental work. They employ about 400 specialists and others in the work of investigation. During the calendar year 1889 the stations published 45 annual reports and 237 bulletins. For further statements regarding station publications, see page 16.

THE WORK OF THE AGRICULTURAL EXPERIMENT STATIONS.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., May 29, 1890.

SIR: Farmers' Bulletin No. 1, of this office, describes the organization, purpose, and general character of the work of the agricultural experiment stations. Farmers' Bulletin No. 2, herewith transmitted for publication, contains a few illustrations of the results of their experimental inquiries selected in part from the report of this office for 1889.

Respectfully,

W. O. ATWATER,
Director.

Hon. J. M. RUSK,
Secretary of Agriculture.

ILLUSTRATIONS OF THE WORK OF THE STATIONS.

The following brief statements regarding the work of the stations in particular lines may help to an understanding of the nature and value of such experimental inquiries. Of course, only a very few of the points of interest or value, presented by the current work of the stations, are here given, the object being simply to indicate some of the ways in which the stations are endeavoring to aid the farmer.

BETTER COWS FOR THE DAIRY.

The need of better cows for the dairy is coming to be very generally appreciated. The dairy commissioner of Iowa is reported as saying that the average cow in that State gives but 3,000 pounds of milk annually, while good ones yield from 5,000 to 6,000 pounds. The director of the Vermont station states that the average yield per cow in that State is only about 130 pounds of butter per annum, while there are thirty dairies in the State that average over 300 pounds per cow.

The director of the New York station says:

> New York has 1,500,000 milch cows, probably producing on an average less than 3,000 pounds of milk per year, and the annual average butter product per cow for the State is undoubtedly less than 130 pounds. This should not be when there are whole herds averaging 300, and some 400, pounds of butter per year for each cow. Animals producing these by no means phenomenal yields are not confined to any particular breed, and are often grades of our so-called native or no-breed animals. Proper selection, systematic breeding, and judicious feeding have produced these profitable animals and herds.

The difference in the milk-producing qualities of different cows is brought out very clearly by a series of experiments conducted at the Massachusetts State station, of which Prof. C. A. Goessmann is director. They are especially interesting because the cows and their feed and care were such as are found on the better farms of Massachusetts, and the results, obtained with the appliances of a well-equipped experiment station, show in accurate and full detail the elements of actual profit and loss as they could not be found in ordinary farm experience.

These experiments have been made with twelve cows and have continued over five years. Grade Jersey, Ayrshire, Devon, Durham and Dutch, and native cows were used. They were secured for the experiments a few days after calving and fed until the daily yield fell below 5 or 6 quarts, when they were sold to the butcher. The length of the feeding period, *i. e.*, duration of the experiment with each cow, varied from two hundred and sixty-one to five hundred and ninety-nine days. Hay, fodder, corn, corn silage, green crops, roots, and corn meal, wheat bran, and other grain were used. The daily ration per head consisted of 18 to 20 pounds of dry fodder, or its equivalent of green fodder, and from 6½ to 9¾ pounds of grain. Careful accounts have been kept of the history of each cow, including breed, age, number of calves, length of feeding period, amounts and kinds of fodder, yield of milk, chemical composition of feed, milk, and manure, cost of cow and feed, and values of milk and manure.

The following is a recapitulation of the financial record of the cows. The milk was reckoned at the price paid for it at the neighboring creameries. The value of the manure produced is calculated by assuming that of the total amount of food 20 per cent would be sold with the milk, and the remaining 80 per cent saved as manure. As farmers in the region buy commercial fertilizers for the sake of their nitrogen, phosphoric acid, and potash, it was assumed that these same ingredients would be worth about as much, pound for pound, in the manure as in the better class of fertilizers, and accordingly the value of the manure was computed by taking the nitrogen as worth 16½ cents, phosphoric acid 6 cents, and potash 4¼ cents per pound. The return for feed consumed represents what the feeder receives for labor, housing of cattle, interest of capital invested, risk of loss of animal, etc.

The most profitable cow was bought for $60, fed five hundred and eighty-four days, and then sold for $28, making her actual cost $32; the feed cost $135.05, so that the total cash outlay was $167.05; the milk brought $203.37 at the creamery; the manure was estimated to be worth $56.93, making the total value received for feed consumed $260.30. Subtracting the total cash outlay of $167.05 from this, there remains $93.25 as net return for feed consumed. Deducting the estimated value of the manure, the remainder, "return in excess of estimated value of manure," is $36.32. In the average for the twelve cows, the net return was $50.43, and the return in excess of the estimated value of the manure only $15.13. With the least profitable cow the cash outlay for cow and feed exceeded the value of the milk and manure by $3.97; in other words, the net return for feed consumed was $3.97 less than nothing. Subtracting the value of the manure, the total loss was $34.25; that is to say, allowing for the value of the manure, the results with the twelve cows varied from a *gain* of $93 to a *loss* of $3.97. Or, if the value of the manure be left out of account, from a *gain* of $36.32 to a *loss* of $34.25.

It is noticeable that the profit or loss did not depend upon either the breed or the length of the feeding period. The most profitable cow, and the least profitable but one, were both of the same breed. Of the two most profitable cows, one was fed for five hundred and eighty-four days, and the other for only two hundred and seventy-eight days.

Two things, then, are brought out very clearly by these experiments. One is that in such localities as this, the value of the manure goes far to decide the profit in feeding dairy cattle. Another is that cows which would ordinarily pass for good ones may differ widely in product.

To the practical dairyman these experiments teach clearly the difference between cows which are profitable and those which are not, and the importance of selecting the best cows for his dairy and getting rid of the poor ones. In a larger sense they illustrate to every farmer the importance of knowing accurately the condition of his business. Upon this its success or failure largely depends.

FIBRIN IN MILK.

Besides feeding experiments with milch cows, a considerable number of the stations have made investigations on subjects relating to dairying, including analyses of milk, butter, and cheese; the devising of methods for testing milk, especially for butter fat; trials of methods of creaming and butter making, and the investigation of creameries. A brief account of two of these investigations is given below.

Dr. Babcock, of the Wisconsin station, has announced the discovery of fibrin in milk analogous to the fibrin of blood. Fibrin is formed in large quantities in blood after it is drawn from the veins and makes the clot. This consists of a dense network of minute threads or fibers in which the blood corpuscles are entangled. A similar clot occurs in milk, though in far smaller quantities. It may be that its formation is due to a ferment, like the fibrin of blood. The fibrin begins to form in the milk as soon as it is drawn from the cow, and the network of fibers entangles the fat globules and hinders their rising to the surface. Fibrin is therefore an important thing in the dairy, since it tends to hinder the separation of the cream. The creaming of milk is helped by anything which retards or prevents the formation of fibrin, and churning is aided by whatever breaks it up. Investigations indicate that in milk, as ordinarily handled, the coagulation of fibrin begins at the surface and in contact with the sides of the vessel; that it is hastened by contact with any rough surface, by agitation, and by exposure to air, and that it is retarded by heat, by cold, and by certain chemicals. Apparently if milk is stirred but little and set as soon as possible after milking in a clean, smooth, metal vessel immersed in cold water, the creaming will take place most efficiently. Bright, smooth tin is excellent for the vessels and ice water for the cooling.

As we shall see beyond, it is probable that the "ripening" of cream is largely effected by the action of bacteria, in breaking up the fibrin which incloses the fat globules of the cream and in making it easier for them to collect into butter when the cream is churned.

BACTERIA IN MILK, CREAM, AND BUTTER.

The following statements have been collated from reports of an investigation on the bacteria of milk, cream, and butter, conducted in behalf of the Storrs station, Connecticut, by H. W. Conn, professor of biology in Wesleyan University.

What are bacteria?—The terms *bacterium* (plural *bacteria*) and *microbe* are used to designate a class of organisms found abundantly in air, water, soil, and in plants and animals. As popularly used the terms include a large number of organisms which the naturalists divide into three classes, bacteria, yeasts, and molds. Bacteria proper, which have most to do with milk and cream, are found in immense numbers everywhere, and play an important part in nature. They are all extremely minute. In shape they show three chief varieties, which may be compared to a lead pencil (*bacillus*), a ball (*coccus*), and a corkscrew (*spirilum*). With the highest powers of the microscope they appear as scarcely more than simple dots and rods. They are to be classed with plants rather than animals, in spite of the fact that many of them are endowed with motion.

What do bacteria do?—Bacteria multiply with the greatest rapidity. A single individual can in a few days give rise to countless millions. While thus growing they produce great changes in the substance in which they grow. Fermentation, such as raising of bread, fermenting of beer and cider, and the formation of vinegar; putrefaction and decay, such as rotting of potatoes and decay of wood, are produced by the bacteria, yeasts, and molds. They are of immense value as well as injury. Through their agency dead animal and vegetable matter is decomposed, and worked over so that plants can use it for food. It is doubtful whether vegetable life could long continue without their aid. On the other hand, many dangerous diseases—cholera, scarlet fever, typhoid fever, consumption, bovine tuberculosis, hog cholera, chicken cholera, etc.—are produced by the growth of micro-organisms in t body. Although bacteria are so very small, there are different speci just as distinct as those of larger plants and animals. The disease germs are mostly parasites upon the animal body, and many of them are unable to live elsewhere. The species of bacteria which produce disease are called *pathogenic* bacteria. But there are many other species which live free in the air and do no injury to animals. It is with these non-pathogenic bacteria that we have to do in the dairy.

Bacteria in milk.—Bacteria collect in milk and cream that have been exposed to the air, grow readily, and multiply rapidly. While growing in the milk they cause it to sour and curdle, and induce other changes in it. Milk, as drawn from the healthy cow, is free from bacteria. Under ordinary conditions, however, it can not be kept free from them, for they will get into it from the hands of the milker, or the teats of the cow, or from the air with which the milk comes in contact. The vessels in which the milk is kept are the most common source of contamination. The bacteria collect upon the sides and in the joints of these, and here develop in the minute portions of milk, grease, or other matters from which it is difficult to free the walls of the vessels.

Effects of heat and cold—How to kill bacteria.—Within certain limits heat increases and cold retards their growth. Different species differ in regard to the temperature at which they grow best. Most species find the best conditions for growth at temperatures between 70° and 100° F. A few will grow quite readily at a temperature below 50° F. A temperature below freezing stops their growth. The heat of boiling water will kill the active forms, but several successive boilings are required to kill their spores (corresponding to seeds). It is not difficult to destroy bacteria after they have once succeeded in getting into the milk. This may be easily done by heating the milk to the boiling temperature for ten minutes upon three successive days. Milk thus deprived of bacteria is said to be sterilized, and if we prevent the further entrance of bacteria by closing the vessel tightly with a plug of cotton, it will remain sweet indefinitely.

Rapidity of growth in milk.—The number of bacteria present in milk depends chiefly upon the length of time that the milk has been standing and upon the temperature. Estimates made upon milk under different conditions have shown from 300,000,000 to 600,000,000 per quart. The effect of temperature is shown by an experiment; a specimen of milk which had been standing for four days in a cold place was found to have about 10,000,000 bacteria per quart. The milk was then allowed to stand in a warm room for seven hours, and during this time the bacteria increased a hundred-fold. From this it appears that the most effective method of preventing milk from souring is to keep it cool. Milkmen sometimes find that the morning's milk in summer sours before the milk of the previous night. It is easy to see why this happens. Milk when drawn from the cow is at a temperature best adapted for bacteria growth. The night's milking is cooled over night. The morning's milk, however, is poured directly into the cans and the bacteria which have entered it are well started upon their growth before the night's milk is warmed by the air. The bacteria in the morning's milk actually get several hours' start, therefore, of those in the cooled milk of the night before. The immediate cooling of milk is thus of great advantage in preventing its souring.

Number of species in milk.—Between forty and fifty species of bacteria have been found in normal milk and cream. This large number is due to the fact that the milk may collect almost any kind of bacteria that may be floating in the air. The individuals of most of the species are few in number and ordinarily are of little significance. A few species are almost universal and extremely abundant.

Different effects of the different species—Souring of milk.—Many of the species cause curdling of the milk. Some of them do this by the production of an acid, and the milk sours. Others curdle the milk apparently by producing a ferment like that in rennet, in which case the curdled milk may not be sour. When a curd is formed it differs in character with the different species. Accompanying the curdling various odors are found, among which may be recognized odors of the cow, the barn-yard, and even the pig-sty. The souring of milk is thus more complex than has been supposed; and while it depends upon the action of bacteria, any of a number of species, or several combined, may be the cause.

The ripening of cream.—Though the presence of bacteria is a nuisance to the milkman it is of positive advantage to the butter maker. The ripening of cream undoubtedly depends upon the presence of bacteria, though it is doubtful whether any one species can produce what is known as ripened cream. Ripened cream contains immense numbers of bacteria. Over 100,000 have been found in a single small drop. Dairymen let their cream ripen before churning, because their experience tells them that the butter separates ("comes") more readily, has a better flavor, and perhaps keeps better. A plausible explanation of the first fact is that the bacteria break up the albuminous matter connected with the fat globules, so that these globules are more easily separated from it and more easily shaken together into large lumps. The products of decomposition usually possess a prominent odor and taste and their presence in the cream probably gives the special flavor to butter made from ripened cream. Pure butter fat is tasteless.

Cleanliness in the dairy.—Few people understand what the thorough cleaning of milk vessels means. A great deal of milk is unnecessarily spoiled by lack of sufficient care to remove all material in which bacteria can grow. Vessels in which milk is kept can not be properly cleaned by pouring boiling water into one, allowing it to remain for a few minutes, and then pouring it into another, thus making one heating do for several vessels. The last ones thus treated will not be much cleaner, so far as bacteria are concerned, than if they were washed with cold water. The use of sal-soda in washing is advantageous, because it acts chemically upon fatty matters, and thus helps to remove these and other materials which adhere to the vessels. In like manner the use of "live steam" to "dry" vessels after washing has the advantage of sterilizing them, *i. e.*, killing the bacteria. As ordinarily used, however, the live steam does not completely sterilize the vessels, since its effects are not allowed to continue long enough. Two minutes' action of live steam is not sufficient to kill the spores of the bacteria that may be hidden in the cracks of the milk vessels.

Practical conclusions.—Three important points in the handling of milk and cream are brought out by these considerations.

(1) The importance of keeping milk so far as possible free from bacteria by the exercise of the greatest cleanliness.

(2) The importance of cooling milk immediately after it is drawn from the cow in order to prevent the souring as long as possible.

(3) The advantage of keeping cream under circumstances favorable to the growth of bacteria that induce ripening.

In brief, vessels in which milk is to be kept should be most carefully cleaned before milk is put into them. As cold retards and heat up to a certain limit favors the growth of bacteria, the advantage of keeping milk cold and cream warm is easily explained.

SILOS AND SILAGE.

Silage, or ensilage, as it is often called, is green fodder which has been more or less completely preserved in an air-and-water-tight pit or box, called a silo. A number of the stations have made investigations regarding methods of building and filling silos, varieties of crops best adapted for silage, growing of crops for this purpose, methods of feeding silage to different kinds of animals, and the chemical and other changes which take place in the fodder while in the silo.

Location and construction of the silo.—The Kansas, Ohio, and other stations have given especial attention to these details. They advise that the silo be as near the feeding place as practicable and on the same level. If, as is very often the case, the herd is fed in a long shed or barn, where the animals stand in stanchions in two long rows facing each other, with an alley between them, the best location for the silo is at one end of the building, with the door of the silo opening opposite the common alley. A root cellar already constructed near the feeding place may, in some instances, be economically converted into a silo, or a bank silo may be used, provided it is so arranged that the silage can be withdrawn at the lowest point. Experience seems to show that wood is the best material for silos. Brick or stone is much more expensive, and the results obtained where either has been used have been much less reliable than with wood. Portions of stone walls belonging to cellars or foundations of barns may be utilized, however, by covering them on the inside with wood. The method of construction which on the whole is to be recommended is in general terms as follows:

On a light foundation of stone set up a strong framework of studding (2 by 8 to 12 inch stuff). On the outside of this frame put a layer of stock boards, and on the inside two thicknesses of matched boards, with tarred paper between. The outside may also be battened and painted, though this is not necessary. A tight roof should be added. A dry and hard dirt floor will answer every purpose. The size of the silo should be proportioned to the number of cattle to be fed. It is better to have it too large than too small. A cubic foot of silage (about 40 pounds) per day per animal seems to be a sufficiently accurate calculation on which to base the size of a silo. From 12 to 15 by 13 to 18 feet, and 22 to 24 feet deep are common dimensions for ordinary silos. If built much larger they should be divided by a partition. The silo should be air-tight and strong enough to resist the great lateral pressure which results from compressing tons of material within a deep box. An experiment at the Kansas station with a silo 13 by 18 feet and 21 feet deep showed the lateral pressure to be about 55 pounds per square foot when the filling of the silo was completed. For about two weeks thereafter there was a small daily decrease in this pressure.

Silage has been successfully fed to a great variety of animals under different conditions, and is very generally considered a valuable substitute for dry fodder or roots. It seems specially adapted to cattle, but is also fed with good results to horses, swine, and poultry. "Silage," says Professor Johnson, of the Michigan station, "is excellent food for dairy cows, producing milk of the best quality."

From experiments at the Wisconsin station the conclusion was drawn "that dairy cows readily consume a sufficient quantity of corn silage to maintain a flow of milk and yield of butter fully equal to and rather more than that produced by feeding dry fodder corn." Besides its other advantages an important consideration is that a larger amount of food can be stored in a given space if silage is substituted for dry fodder. The idea that the small farmer can not afford the silo is strongly controverted by Professor Johnson. "The small farmer with limited area of land is necessitated to crop more continuously than his neighbor with a much larger acreage. He needs in every possible way to secure the fertilizing material that shall replace the drains that this closer cropping is making on his fields. How can he do it so cheaply, so surely, as by growing large crops of silage corn that will give him the main fodder necessary to enable him to feed for the market or the dairy through the winter much more stock than his acres will carry in the summer?" In a recent experiment in Kansas, "the actual cost of cutting up the corn, hauling it 50 rods to the silo, and storing it therein was 62 cents per ton. This includes fuel for the engine, but no charge is made for the use of machinery." Professor Shelton, under whose directions the experiment was made, has no doubt that this expense might be greatly reduced.

Corn silage is not a complete ration, but should be fed in connection with some hay or other dry fodder and grain, oil-meal, cotton-seed meal, wheat bran, or other nitrogenous food. This follows from the fact that corn contains an excess of carbohydrates (*i. e.*, substances which serve the body for fuel or are transformed into fat), and should, therefore, be combined with feeds containing more nitrogen to form a well-balanced ration. Silage alone, however, may in some cases produce better results with less expense than are obtained with hay as an exclusive diet.

It is generally agreed that corn is the best crop for silage in this country. Dent varieties are preferred in most cases, though Southern or silage varieties are recommended by some experimenters because of the large yields they give, and in the extreme North certain of the flint varieties may be used to the best advantage. In some localities, as in Kansas and other Southern States, sorghum is a very important crop for silage. The Kansas station recommends medium-growing saccharine and the non-saccharine varieties for silage, and especially Golden Rod, Late Orange, and Goose Neck. The sorghums have some advantages over corn. "They are less liable to damage by insects and they remain green far into the fall, usually until cut by frosts, so that the work of filling the silo may be carried on long after the corn plant has ripened its crop and the stalks have become worthless." Clover, alfalfa, cow-peas, and other forage plants have been successfully used for silage, but corn and sorghum will undoubtedly continue to be the principal crops used for this purpose.

Corn for silage should be planted early enough in the season to secure the proper maturity. The time of planting will vary from May 10 to June 15, according to locality, season, and variety of corn. The seed should be planted in drills 3 to 3½ feet apart. The Ohio station advises about twelve quarts of seed per acre for most cases, though with some of the larger Southern varieties fifteen quarts may be necessary. There is still considerable variety of opinion as to the proper time for harvesting the crop, though the recent investigations seem to favor greater maturity than was formerly thought desirable. Chemical analyses recently made at the New York station indicate "that for the greatest amount of nutriment, considered from a chemical standpoint, corn should not be cut before it has reached the milk stage of the kernel." In Ohio it is recommended by the station that "fodder corn should be cut when the corn begins to glaze and when the stalks begin to dry near the ground." But in Kansas, where intense heat and other climatic peculiarities hasten the ripening of the crop, it is thought that harvesting "should not be delayed after the corn is in the early dough state."

It is now quite generally thought better to put both stalks and ears in the silo than to use the stalks alone for silage. Before being placed in the silo the corn should be cut into small pieces. Some experimenters prefer one-half-inch lengths, as these will pack more evenly and solidly than longer pieces. It is a good practice to keep a man in the silo while it is being filled to see that the silage is packed as closely in the corners and along the sides as elsewhere. If the filling occupies much time, so that the silage becomes heated, some of the heated silage near the sides should be from time to time thrown into the center and replaced with the warmest silage, so as to keep the temperature of the whole mass as even as possible. It seems to make little difference whether the filling is continuous or extended over several days, provided the work is carefully and thoroughly done. There is no agreement among experimenters as to the necessity of weighting the silo. At the Ohio station a wooden cover made of flooring boards well fitted together was placed on the silo. On this was placed about a ton of sand in boxes, and round the edge of the cover next the silo walls a piece of inverted sod to prevent the entrance of air. After the silage had settled about 2 feet, a ton of grass was thrown over the boxes of sand. In Kansas a layer of tarred paper, covered about 18 inches deep with green grass, has been as effectual as weighting heavily with rocks.

Fermentation in the silo.—Recent investigations by Professor Burrill, of the Illinois station, emphasize and help to explain the fact that silage is necessarily a very variable product, requiring careful treatment. The corn or other material used for silage varies in maturity, in chemical composition, and in amount of moisture. Numerous and diverse chemical changes take place in the silo, and the fermentations due to the action of the minute organisms classified as yeasts, bacteria, and molds, are varied and complex. Until very lately people have had very little idea of the influence of bacteria and other ferments in the operations of the farm. On pages 6–9 of this bulletin a brief explanation is given of the nature and work of these organisms. Much remains to be found out concerning their action in the silo, for studies in this line are only just begun.

The kinds of ferments which cause changes in the silo include (1) yeasts, which cause the change of sugar into alcohol and other fermentations; (2) bacteria, which cause the formation of acids and the heating in the silo, and appear to aid in the destructive changes, notably the semi-putrid decomposition, accompanied by bad odors, which so often occurs in old silage; (3) molds, which also cause putrefaction. The yeasts found in the silo do not appear to be such as cause ordinary alcoholic fermentation, and it is doubtful if ordinary alcohol occurs in silage. The hot fermentation which often takes place soon after the silo is filled, though not yet fully explained, is not due to yeast. Two or more species of bacteria appear to be concerned in the raising of the temperature. These bacteria are similar to those which cause butyric fermentation, *i. e.*, the formation of butyric acid which is found in rancid butter. The high temperature does not destroy the bacteria and molds which later cause acid fermentation and putrefaction. After the heating, however, the silage settles and the air is excluded. The initial high temperature which these bacteria induce is, therefore, probably most serviceable by causing this closer packing of the silage and the exclusion of the air, rather than by killing the germs of other ferments.

Ferments which induce the formation of acetic acid in vinegar and of lactic acid in milk are active in the silo, and if allowed to act produce much acid and make the silage sour. Silage from corn, however treated, contains the acid originally in the stalks. "Sweet silage" is that which has in addition only a small quantity of the acids formed by fermentation. What commonly passes for sweet silage is not always the same thing. It may be obtained either with or without heat. By the process of rapid filling and close packing, especially with the more mature and dry corn, the mass remains sweet, simply because little fermentation of any kind takes place in the silo. If, on the other hand, the silo is filled slowly, the mass soon becomes very hot. This high temperature is due to the action of bacteria. After the heating the silage settles and the air is excluded. In this way fermentation is largely prevented and the silage remains comparatively sweet. Since air and moisture favor the fermentations which injure silage, it follows that mature corn, containing less water than that cut earlier, and close packing in an air-tight silo are needed to produce the best silage.

ALFALFA.

Alfalfa or lucern (*Medicago sativa*) is a perennial forage plant resembling clover in its feeding value, habits of growth, and effects on succeeding crops. Under favorable conditions it will live from eight to fifteen years, and does not run out as clover does. It has long been cultivated in Europe, and is grown quite extensively in California and some of the Western and Southern States. It seems probable that it may be introduced with advantage into many parts of the Southern States east of the Mississippi, and over a wide tract of the more arid regions of the Southwest. It has been grown successfully for the past seven years at the station at Geneva, New York, but in recent experiments on thirty farms in different parts of Vermont it was very largely winter-killed. While a southern climate is more favorable to alfalfa, numerous experiments have shown that it will do well in many localities in the Northern States, and when established will produce from three to five crops each season for a number of successive years. "Alfalfa is especially adapted to dry climates, and withstands drouth much better than ordinary clovers." For this reason it is largely relied on in Colorado and California, especially where irrigation is used.

Soil.—Alfalfa prefers a light, sandy, or loam soil, with a subsoil through which its long roots can penetrate. In some cases its tap-root goes down 12 to 15 or even 20 feet. At the New York station, however, alfalfa has been successfully grown on a clay soil. On such a soil greater pains must be taken to secure a good stand, but when the plant is once established the character of the subsoil is of more importance than that of the surface soil.

Culture.—Use fresh and pure seed. Sow at any time when the ground is in suitable condition, and when there will be time for the plants to become well established before they are subjected either to drought or extreme cold. The soil should be thoroughly prepared, and the seed sown at the rate of 15 to 20 pounds to the acre. If sown broadcast, about the latter quantity will be required; if in drills, the former amount will be sufficient.

In regions where irrigation is necessary the Colorado station advises that the water should be applied to alfalfa before cutting, because thus the mower does its work more effectively and the growth of the succeeding crop is stimulated.

Harvesting.—Alfalfa should be cut during the first period of good weather after the blossoms begin to appear. If allowed to stand too long, its stalk becomes hard and woody and succeeding crops are likely to be diminished. If designed for hay, it must be carefully cured and housed, for otherwise its leaves will drop off and only a mass of bare stalks be left.

As a collector of plant food.—The mineral constituents of plants, such as phosphoric acid, potash, and lime, are derived solely and entirely from the soil. Nitrogen, on the other hand, may be taken into the plant from the air or from the soil. It now seems certain from experiments in Europe and by the Storrs station in Connecticut that alfalfa, clovers, peas, and many other plants belonging to the class called legumes gather a part of their nitrogen from the air. The plants which have this power may be called nitrogen collectors. The legumes contain large quantities of nitrogen in the form of protein. The protein compounds form blood, muscle, tendon, bones, and other nitrogenous tissues; hence the legumes are especially valuable for fodder. Furthermore, nitrogen is the most valuable constituent of manures, and is by far the costliest ingredient of commercial fertilizers. Plants which have the power of gathering nitrogen from the air have, therefore, a twofold advantage for the farmer. As fodder, they supply the protein which corn, corn-stalks, silage, straw, the poorer qualities of hay, and many other food materials lack for making meat and milk and giving animals strength for work. When they are plowed under or fed to stock and the manure returned to the ground they supply the nitrogen which other crops, such as wheat, rye, oats, grasses, root-crops, and potatoes are unable to acquire for themselves.

As a feeding stuff.—During a single season alfalfa furnishes a large amount of nutritious green forage, relished by all kinds of stock. It should be partially wilted or mixed with hay or straw. In the dry regions of the West it is much used for pasture, especially in the fall, but there is more or less danger that it will cause the cattle to bloat or that the plants will be killed by close pasturing. Cattle, sheep, and horses relish alfalfa hay and seem to thrive on it.

Chemical analyses and digestion experiments show that alfalfa compares very favorably with red clover both as green fodder and as hay. It may be used either for fattening or for milk. To secure a well-balanced and economical ration, alfalfa, which contains a large proportion of protein, should be fed with corn, wheat or oat straw, root crops, etc., which contain relatively large amounts of the other food ingredients (carbohydrates and fat). In many instances farmers might profitably raise alfalfa as a substitute for the wheat bran, cotton-seed meal, and other materials which contain large amounts of protein, and which they are now buying in order to utilize the excess of carbohydrates produced in corn and other crops.

Disadvantages of alfalfa.—(1) It is not easily established.

(2) It is less hardy than clover.

(3) If allowed to grow too long its stalks become hard and woody.

(4) Except in dry regions cattle can not be safely pastured on it.

(5) It requires peculiar treatment to make good hay.

Advantages of alfalfa.—(1) When established it does not run out.

(2) It withstands drought much better than clover.

(3) It grows rapidly and may be cut early in the season.

(4) It gathers a large amount of nitrogen from the air as well as from the soil, and is therefore very valuable as a fertilizing crop.

(5) It furnishes several large crops of green fodder each season.

(6) When properly cured it makes an excellent hay.

(7) It is relished and digested by all farm animals and is an excellent flesh and milk producer.

(8) It makes muscle rather than fat, and is therefore valuable to use with corn and other fat-producing crops to make a well-balanced ration for cattle.

In brief, experience at the stations and elsewhere indicates that alfalfa is valuable as a feeding-stuff and as a fertilizing crop, but that it requires peculiar conditions of climate and soil for growth, and careful culture and curing to make it a profitable crop. It is worthy of repeated and systematic experimental tests by farmers, even though in some regions and on some farms it should prove a failure.

FIELD EXPERIMENTS WITH FERTILIZERS—SOIL TESTS BY FARMERS.

Farmers in the older States are spending millions of dollars annually for commercial fertilizers. In this country, as in Europe, they have become an absolute necessity on worn-out soils; but to make them profitable it is necessary that they should fit the wants of the soil and crops for which they are used. If a farmer buys potash for land which abounds in potash but needs phosphoric acid, he of course loses. The fundamental principle in the use of commercial fertilizers is to select those materials which supply in the best forms and at the lowest cost the plant food which the crop needs and the soil fails to furnish.

In order to enable farmers to find out the wants of their own soils and the best ways of supplying them, and at the same time to get light upon the properties of soils in different sections of the country, a number of the stations are introducing soil tests with fertilizers, which are largely conducted both by the stations and also by individual farmers on their own farms. Of course, many of the experiments are failures, but many practical men who have engaged in this work have declared that they have thus learned a great deal which is practically useful and highly instructive. A general plan for such experiments may be found in Circular No. 8 of this office.

The results of these tests in general show that "soils vary greatly in their capabilities of supplying food to crops. Different ingredients are deficient in different soils. The best way to learn what materials are proper in any given case is by observation and experiment. The rational method for determining what ingredients of plant food a soil fails to furnish in abundance, and how these unfurnished materials can be most economically supplied is to put the question to the soil with different fertilizing materials and get the reply in the crops produced. The chief use of fertilizers is to supply plant food. It is good farming to make the most of the natural resources of the soil and of the manures produced on the farm, and to depend upon artificial fertilizers only to furnish what more is needed. It is not good economy to pay high prices for materials which the soil itself may yield, but it is good economy to supply the lacking ones in the cheapest way."

FARMERS AS EXPERIMENTERS.

A most gratifying outcome of these experiments is the demonstration they give of the capacity of our intelligent farmers for experimenting. Not only do many of them work with true scientific spirit, commendable accuracy, and marked success, but the results they obtain are of the greatest value for their communities as well as for themselves. It would be easy to cite a large number of cases in point. In the carrying of science to the farm and combining it advantageously with practice, in the development of talent for experimenting among farmers, and in thus making the experimenters teachers in their communities, are to be found some of the most satisfactory of the many encouraging features of the experiment station movement in the United States.

PUBLICATIONS OF THE STATIONS AND THIS OFFICE.

Each station issues bulletins and annual reports, which are sent free of charge to citizens of its own State and, so far as circumstances will allow, to applicants from other States. The work of the stations is also summarized in publications of this office.

The Office of Experiment Stations issues two classes of publications for general distribution: 1. Farmers' Bulletins, which are brief and popular in character, and are sent on application. 2. Experiment Station Bulletins and the Experiment Station Record, which are more or less technical. It is the practice to send to persons applying for them one or more numbers from which they may judge of their usefulness, but not to place any names upon the mailing list until after receipt of a special application on blanks furnished by the office.

Communications intended for this office should be addressed to the SECRETARY OF AGRICULTURE for the *Office of Experiment Stations, Department of Agriculture, Washington, D. C.*

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 3.

AGRICULTURAL EXPERIMENT STATION

CULTURE

OF

THE SUGAR BEET,

BY

H. W. WILEY,
CHEMIST OF THE DEPARTMENT OF AGRICULTURE AND DIRECTOR OF THE
DEPARTMENT BEET-SUGAR EXPERIMENT STATION IN NEBRASKA.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Chemistry,
Washington, D. C., March 2, 1891.

Sir: The inquiries which the Department is daily receiving for information concerning the growth of sugar beets are so numerous as to render necessary the publication of a special circular of information. An elaborate discussion of the subject was presented in Bulletin No. 27, but the edition was so small as to render it impossible to send it to all who make inquiries. In the present publication an attempt will be made to present in a condensed form the data in possession of the Department concerning which the most frequent inquiries are made. No attempt will be made to elaborately discuss any of the points connected with the manufacture of beet sugar. Those who are particularly interested in this matter may still be able to obtain copies of Bulletin No. 27 before the original edition is entirely exhausted.

H. W. Wiley,
Chemist.

Hon. J. M. Rusk,
Secretary of Agriculture.

FARMERS' BULLETINS.

The bulletins of this series may be obtained by applying to the Secretary of Agriculture, Washington, D. C. The following have been previously issued:

Farmers' Bulletin No. 1. The What and Why of Agricultural Experiment Stations. (A brief explanation of the object, origin, and development of the stations, their work in Europe and in the United States, and the operations of the Office of Experiment Stations of the Department of Agriculture.) Prepared by the Office of Experiment Stations. pp. 16. Issued June, 1889.

Farmers' Bulletin No. 2. The Work of the Agricultural Experiment Stations. (Illustrations of station work in the following lines: better cows for the dairy; fibrin in milk; bacteria in milk, cream, and butter; silos and silage; alfalfa; and field experiments with fertilizers.) pp. 16. Prepared by the Office of Experiment Stations. Issued June, 1890.

IN PRESS.

Farmers' Bulletin No. 4. Fungous Diseases of the Grape and their Treatment. By B. T. Galloway, Chief of the Division of Vegetable Pathology.

THE CULTURE OF THE SUGAR BEET.

By H. W. Wiley,
Chemist of the Department of Agriculture, and director of the Department Beet-sugar Experiment Station in Nebraska.

CLIMATIC CONDITIONS FAVORABLE TO THE GROWTH OF THE SUGAR BEET.

Experience has shown that the sugar beet reaches its highest development in north temperate latitudes. So far as the production of the beet with high tonnage is concerned, it is found that it will grow far to the south, but beets grown in such localities, upon the whole, are less rich in sugar and less suitable for the manufacture of sugar than those grown further north. It must be remembered, however, that the expressions north and south do not refer to any absolute parallels of latitude, but rather to isothermal lines, which in many cases run obliquely to the parallels of latitude and in some cases cross them almost at right angles. As a result of many years of careful experimentation, it may be said that as far as temperature alone is concerned the sugar beet attains its greatest perfection in a zone of varying width through the center of which passes the isothermal line of 70° F. for the months of June, July, and August. This zone is shown in a map in Bulletin No. 27.

This isothermal line, for the United States, begins at the city of New York and passes up the Hudson River to Albany; thence turning westward it runs near Syracuse and passes in a southwesterly direction, touching the shore of Lake Erie near Sandusky, Ohio; turning then in a northwesterly direction it passes into Michigan and reaches its highest point in that State near Lansing; then passing in a southwesterly direction it enters the State of Indiana near South Bend, passes through Michigan City, then in a northwesterly course continues through the cities of Chicago and Madison, reaching its highest point near St. Paul, Minnesota. Thence it passes in a southwesterly direction until it enters the State of South Dakota, thence it turns again northwest and reaches its highest point in Dakota just above the forty-fifth parallel of latitude where it crosses the Missouri River. The isothermal line then turns almost due south, following very closely the one hundred and first degree of longitude until it leaves the State of Nebraska near the northeast corner of Colorado; passing through a southwesterly direction through Colorado, it reaches, at Pueblo, almost to the one hundred and fifth degree of west longitude, whence it passes in a slightly southeasterly direction into New Mexico, turns to the west, and crosses the one hundred and fifth degree of longitude at about the thirty-second degree of latitude. Then turning westward it passes in a very irregular line through the States of California, Oregon, and Washington.

Extending a distance of 100 miles on each side of this isothermal line is a belt which, for the present, may be regarded as the beet sugar area of the United States. There are doubtless many localities lying outside of this belt, both north and south, in which the sugar beet will be found to thrive; but this will be due to some exceptional qualities of the climate or soil and not to any favorable influence of a higher or lower temperature. A mean temperature of 70° F. in the summer, however, must not be regarded as the only element of temperature which is to be taken into consideration. In those localities where the winters come early and are of unusual severity will be found greater difficulties in the production of sugar from the sugar beet than in those localities where the winters are light and mild, although the mean summer temperature of both localities may be represented by 70° F. As an illustration of this difficulty may be cited northern Nebraska and South Dakota where the winters are of great severity and southern California where there is scarcely any winter at all.

The mean summer temperature of these localities is about the same, but the continuation of a summer temperature through the winter in southern California will greatly favor the manufacture of the beets. In northern Nebraska and South Dakota the beets which are to be manufactured during the winter time have to be protected by expensive silos. In southern California and other places similarly situated the beets can be protected without any covering, or at most with only a slight covering of leaves or straw. The season for planting in a mild climate is also longer; for instance, in southern California planting can commence as early as February and continue till June, thus giving a beet crop coming continuously into maturity from the 1st of August to the 1st of December. In other localities the planting must be accomplished in a short time, say from the 10th of May till the 1st of June. Before the first of these dates the ground will be too cold for planting, and after the second the season will be so late as to prevent the maturity of the beets before frost.

Although conditions of temperature must be taken into consideration in selecting sites for beet-sugar factories, yet in addition to the thermal conditions must also be taken those of rainfall. The sugar beet requires a certain amount of moisture in order to produce its normal crop. This moisture must be derived either from precipitation, in the usual way, or else the soil must be of that particular quality which will allow subterranean moisture to reach the rootlets of the plants. Soil of this latter kind appears to exist in many localities in California where beets are grown absolutely without rain. The porous and sandy soils surrounding many of the western rivers, such as the Platte River in Nebraska and the Arkansas River in Kansas, also appear to furnish a sufficient amount of subterranean moisture to produce a good crop in connection with the rainfall, of which little is expected in those localities during the summer months. We should, however, endeavor to secure localities for the growth of the sugar beet where we may expect an average summer precipitation of from 2 to 4 inches per month. There are many conditions of agriculture under which the beet becomes quite independent of extremes of precipitation. The beet may thrive with very little rainfall or with a great deal, if properly cultivated in suitable soil.

VARIETIES OF BEETS.

All kinds of sugar beets are botanically identical with the common garden beet, *Beta vulgaris*. The differences in varieties have arisen by reason of special selection and culture, producing a pure strain of some valuable peculiarity in the beet. These accidental valuable qualities, by careful selection, have become fixed, and are associated with certain external properties which have thus come to be regarded as distinguishing characteristics.

The shape and size of the beet, its color, the character of the foliage, whether erect or spreading, etc., are the most frequent marks of distinction. The beets are also frequently designated by the names of those who have developed them, or by the name of the town or locality in which they have been grown, or by their color.

Among the more frequently occurring varieties grown in Europe may be mentioned the Vilmorin Improved, Klein Wanzlebener, Improved Klein Wanzlebener, White Excelsior, White Imperial, Simon Le Grande, Florimond and Bulteau Desprez Richest, Brabant Sugar Beet, Rose Imperial, etc.

The two varieties which have been most widely grown in this country are the Vilmorin Improved and the Klein Wanzlebener. The certainty that the seed has been grown according to the most scientific methods is of greater importance to the beet grower than the variety. The beet has reached such a high state of perfection as to make the least degree of laxity in its treatment exceedingly dangerous to its qualities.

SOIL.

The sugar beet does not require a particular kind of soil for its proper production. In general, soils are described for practical purposes as clayey, sandy, loamy, or alluvial soils; all of these soils will produce beets. The black prairie soils also have been found, with proper cultivation, to produce excellent beets. Generally, the least favorable soils for the sugar beet are a stiff clay, which is cultivated with difficulty and readily packs under the influence of hard rains and hot suns, and virgin soils or those especially rich in organic matter or alkaline salts. Perhaps the best soil may be described as a sandy loam; a soil containing a happy equilibrium between organic matters, clay, and silica.

In general it may be said that any soil which will produce a good crop of Indian corn, wheat, or potatoes will, under proper cultivation, produce a good crop of sugar beets. The soil on which sugar beets are grown, however, should be reasonably level, and this being the case it should be well drained. Natural drainage on level soil being somewhat deficient, it is most imperative that tile drainage be practiced. It would be useless to attempt to raise sugar beets on level land without tile drainage, especially in a rainy season.

FERTILIZATION.

Happily, in most American soils there is still sufficient natural fertilization to produce a good crop of sugar beets; while in the soils of Europe, where sugar beets have been grown for years, the farmers must depend on fertilizers to insure a remunerative crop.

Two kinds of fertilizers are employed: stall manure from the farm, and artificial manure generally known as commercial fertilizers. For general purposes, stall manure is better. It should be applied, in a well-rotted condition, in the autumn before the ground is plowed. The quantity per acre depends, of course, on the fertility of the soil; but in any case it is not best to apply a very heavy dressing. In poor soils it is best to apply the fertilizer for several years in succession, rather than to apply enough at once to bring it up to the required state of fertility. Too copious an application of stall manure is apt to produce overgrowth in the beets, which makes them ill-suited to the manufacture of sugar. If the fertilizer be applied in an unrotted condition, it is apt to seriously injure the crop in case of dry weather.

Of commercial fertilizers three classes are employed, containing respectively nitrogen, phosphoric acid, and potash. In some instances these three elements are found combined in the same commercial fertilizer. Nitrogenous manure should be applied with great care to sugar beets. It tends to produce a very heavy growth of the beet, and thus to diminish its content of sugar. Potash and phosphoric acid can be applied with great freedom to beet fields; they act much better in conjunction than when applied separately.

The principles of fertilization depend upon the fact that the soil should have returned to it all that the harvest has removed in respect to mineral substances and nitrogen.

Nothing can be more certain than that a soil to which this restoration is not fully made will gradually lose its faculty to produce plants in normal quantity and composition. Culture experiments with artificial food liquids have not been carried so far with the beet as with some other plants and, therefore, the dependence between the composition of such liquids and the evolution of the beet has not yet been determined. The basis is also wanting whereon the direct working of the manure on the beet can be predicted; and here is met the well-known difficulty of getting the manures into those layers of the soil from which the beet chiefly draws its supplies.

Since experience has taught that beets raised on fields freshly manured with stable manure are inferior for purposes of manufacture, the rule has long been established that not the beets, but the previous crop should be fertilized, or that the beets should be raised in rotation as the second or even third crop. Unfortunately this rule, so important to the factories, is not always observed, and as a consequence of heavy manuring heavy crops have been produced, but at the cost of diminished sugar content or lessened price. This rule applies especially to stable manure and night-soil, as well as to Chili saltpeter, the misuse of which has had such serious consequence for factories, but not to phosphatic manures, which usually exert a favorable influence upon the crop.

The constituents to be taken into account in the necessary restitution to the soil for beets are potash, phosphoric acid, magnesia, and nitrogen. Following are the quantities of these constituents in 1,000 pounds of beets and beet leaves, averaged from numerous analyses:

Constituents.	Roots.	Leaves.
	Pounds.	*Pounds.*
Potash	3.3	6.5
Phosphoric acid	0.8	1.3
Magnesia	0.5	3.0
Nitrogen	1.6	3.9
Total ash	7.1	18.1

It will be seen from the relation between the roots and leaves that the amounts abstracted by the latter are considerably greater and deserve especial consideration in case the leaves are not left in the field. From this point of view the leaves should be left in the field. It is certain that a complete restitution can not be made otherwise. The form in which the above-mentioned plant constituents shall be returned to the soil is established for phosphoric acid and magnesia, and partly for nitrogen; superphosphates, with greater or less content of phosphoric acid, or with addition of nitrogenous element, are of universal application. As has been shown by direct investigations, the magnesia is nearly all returned in the press cakes from the factory, though a more uniform distribution is much to be desired.

The soil ingredients most essential for successful production of the sugar beet are nitrogen, phosphoric acid, potash, lime, and magnesia.

Most soils contain a sufficient quantity of magnesia, and the press cakes from the factory, which should be returned to the soils, will supply any deficiency. The same is true in regard to lime, although there are soils in which the supply of lime is naturally deficient. Such soils would be benefited by an application of land plaster, burned lime, or ground shells. Phosphoric acid and potash are supplied in the form of ordinary commercial fertilizers, as ground bone and kainite or as superphosphate combined with some potash salt. Of the various potash compounds found in natural deposits none are to be preferred to others; preference is due only to compounds with organic substances. Consequently the molasses, or its residue after distillation and the liquors of the molasses-working processes, all rich in potash, are themselves most valuable materials for potash fertilization and should be carefully preserved for such use. It must not be supposed, however, that the demand for potash will be satisfied by returning to the soil the molasses from the crop of beets in the form of waste products. Aside from the leaves, for which if taken from the field a largely increased potash return must be made, the molasses itself does not represent the entire amount of potash taken. Factories which produce raw sugar sell with it also potash, and in all factories the waste waters carry potash compounds sufficient to account for the difference between the amount of potash in the beets and in the molasses.

Phosphoric acid is best supplied in the form of ground bone, superphosphate, or basic slag from the blast furnaces. Nitrogen may be supplied in the form in which it exists in ground bone or from the refuse of the slaughter houses in the form of dried blood and tankage, or as cotton-seed meal or oil cake, or as nitrate of soda.

As for the relation which the quantity of material returned should bear to the quantity abstracted, it may be said in general that it is desirable to return as much nitrogen, one and a quarter to one and a half times as much potash, and two and a half times as much phosphoric acid as has been abstracted. The greater additions of potash and phosphoric acid have no disadvantageous effects upon the crop. Direct investigations in regard to the relation between the sugar and potash in consecutive crops for many years have failed to give the least ground for a contrary conclusion. But it must not be expected on the other hand that increasing fertilizations, especially potash fertilization, will produce proportionately increasing crops, as has been asserted by some.

EFFECT OF NITROGENOUS MANURES ON THE QUALITY OF THE BEET.

The opinion has generally prevailed among beet-growers during late years that heavy nitrogenous manuring, especially with nitrate of soda, produces no injurious effect on the quality of the beet. This opinion was based on the fact that in such beets the sugar per cent. was only slightly diminished. Nevertheless the quality of a beet may be impaired even with little or no diminution of the sugar content by reason of the increase of the percentage of non-sugars present.

It has been shown that heavy manuring with nitrogenous substances greatly injures the quality of the beet for sugar-making purposes. The apparent coefficient of purity of the juice is also frequently misleading since it take no account of the nature of the non-sugars present.

The real purity of the beet is also to be distinguished from the apparent purity of the juice. The real purity of the beet is obtained by dividing the percentage of sugar in the beet by the total solid matter therein; the apparent purity of the juice by dividing the percentage of sugar therein by the apparent percentage of solids as indicated by the Brix spindle. Judicious fertilizing with nitrate of soda, however, is beneficial.

ROTATION.

Beets do best after wheat or some other cereal. It is true that soils on which beets have not been grown, as the soils of this country, may produce beets for several years without harm. Nevertheless, proper rotation is always desirable.

A good scheme of rotation is, first wheat, then beets, then clover, one crop of which is cut for hay and the second crop plowed under, then potatoes, wheat, and beets in the order mentioned. By this method and a judicious use of stall manure and commercial fertilizers, the fertility of the soil can be maintained and even increased. Beets should follow wheat or a cereal crop, because this crop being harvested early leaves the ground ready for autumn plowing, a prerequisite to successful beet culture.

PREPARATION OF THE LAND FOR PLANTING.

The field in which beets are to be planted should be selected and plowed in the autumn to the depth of at least 9 inches. The plow in each furrow should be followed by a subsoiler, which will loosen the soil to the depth of 6 or 7 inches more. A convenient subsoil plow is shown in Fig. 1. Each field to be planted in beets should thus have the soil prepared by thoroughly loosening it to the depth of from 15 to 18 inches. The land being exposed through the winter becomes quite mellowed,

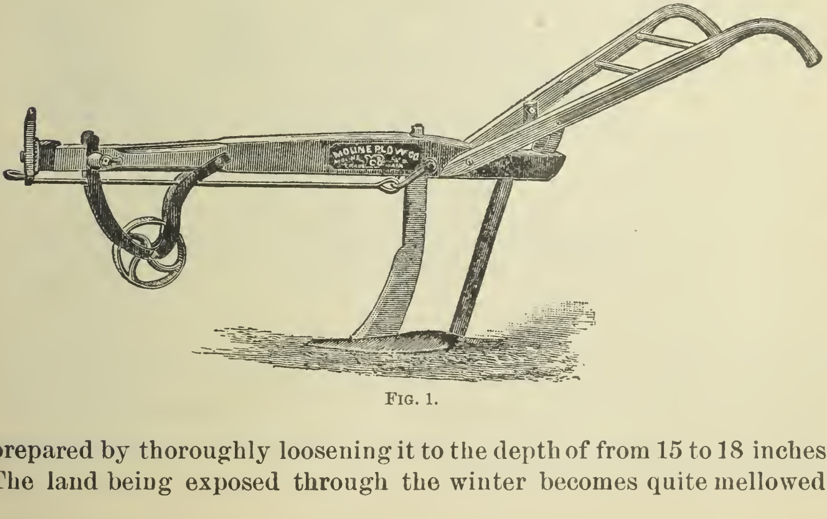

FIG. 1.

and in the spring can be prepared for planting by a simple preparation of the surface. This should be done by a thorough cultivating until the surface of the soil is reduced to perfect tilth, and it then can be marked out for planting. No further preparation is necessary. It is desirable, however, that each portion of the field to be planted should be thoroughly prepared immediately before the planting takes place. For instance, if the planting is to be made on a given day, the soil should be thoroughly prepared on the previous day. Thus all weeds and grasses which have started to grow are killed, and the beets have an even chance with the weeds for growth. If, on the other hand, the soil be prepared several days or even a week before planting, the weeds and grasses get a good start and it is difficult then for the beets to thrive.

PLANTING.

The beets may be planted either by hand or by drill. Hand planting is preferred when a very small plot is to be put in beets, but where a field embracing several acres is to be planted, hand planting becomes too slow. In such cases planting by drill is best. Almost any garden drill can be adapted to use with beet seed. A special drill for sugar beet seed is furnished by the Deere-Mansur Company, of Moline, Illinois. It is represented in Fig. 2. The form of drill represented in Fig. 3 may also be used. In hand planting the beets may be placed in hills, several seeds being planted in each hill, and thus the cultivation of the beets be facilitated. In planting by drill it is necessary to plant from 15 to 20 pounds of seed per acre; in planting by hand from 10 to 15 pounds will be found sufficient.

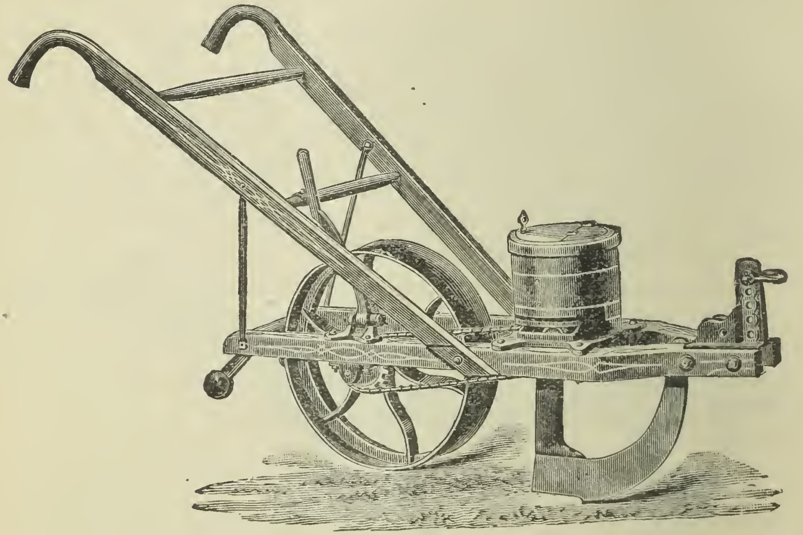

Fig. 2.

The beets should be covered to the depth of one-half to one and one-half inches, according to the condition of the soil. If the soil be moist and in excellent condition the beet seed should not be covered more than half an inch. If, on the other hand, the soil be very dry, they should be covered to the depth of one and a half inches.

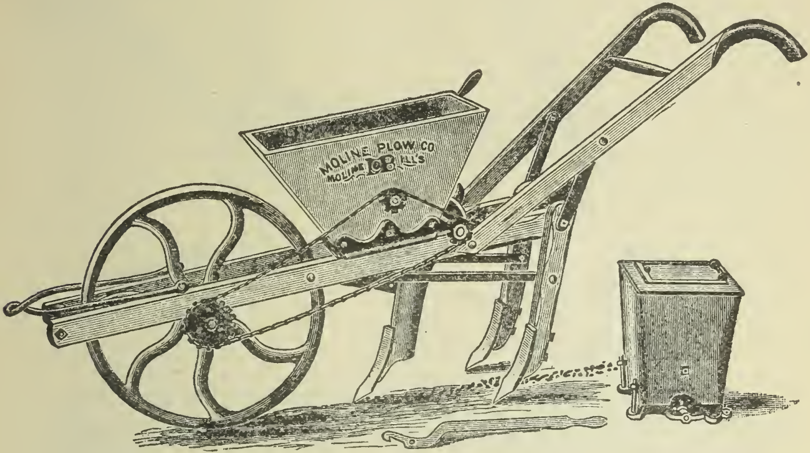

FIG. 3.

CULTIVATION.

As soon as the beets are large enough to mark the rows, cultivation with the horse or hand hoe may be commenced. This is essential if the grass and weeds appear above ground at the same time.

When large fields are cultivated the horse hoe, made by Bajàc, ot Paris, shown in Fig. 4, may be used. For smaller fields a similar apparatus, drawn by hand, may be employed. Convenient instruments ot this kind are shown in Figs. 5 and 6. This plow frees the spaces between the rows of beets from weeds and yet prevents the growing beets from being covered by the loose soil.

When the beets show four leaves the process of thinning should take place. If the rows be 18 inches apart a vigorous plant should be left every 8 to 10 inches. Careful selection should be made and all the puny plants destroyed. It is better to save the vigorous plants even if regular intervals are not preserved, but no space should be left greater than 12 to 15 inches in extent. Much of the thinning work can be done by a narrow hoe, but where the plants are very close together, at the place where the preserved plant is to grow, the work must be done by hand. It is well to have a thorough hand hoeing at the same time, and the subsequent cultivation, in most seasons, may be carried on with horse-power.

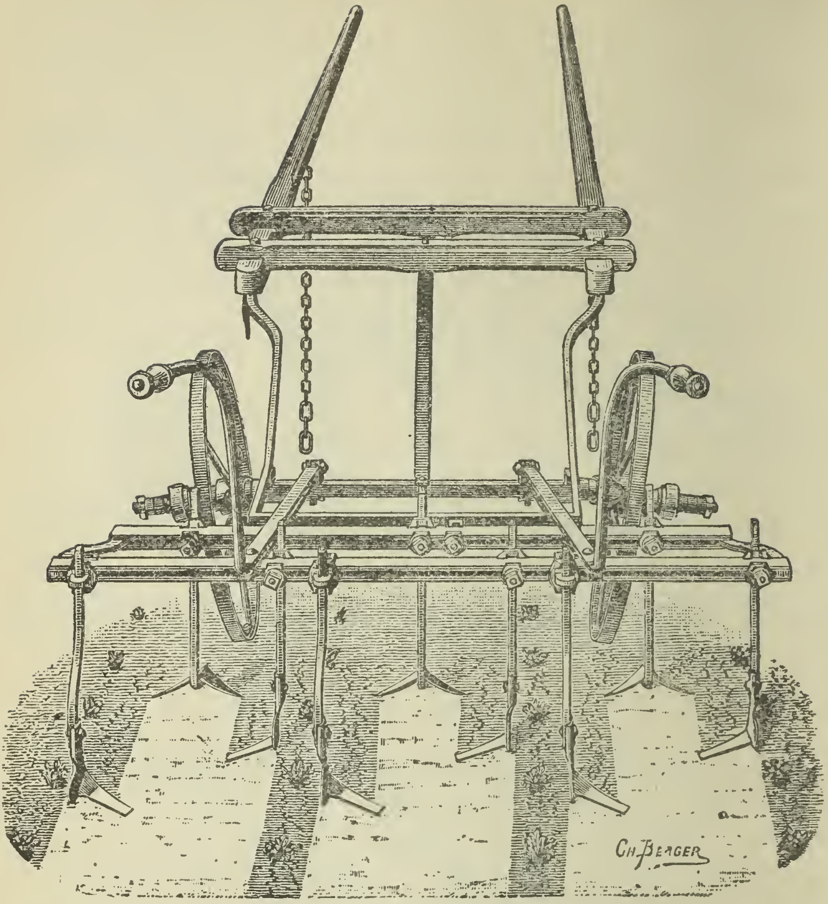

FIG. 4.

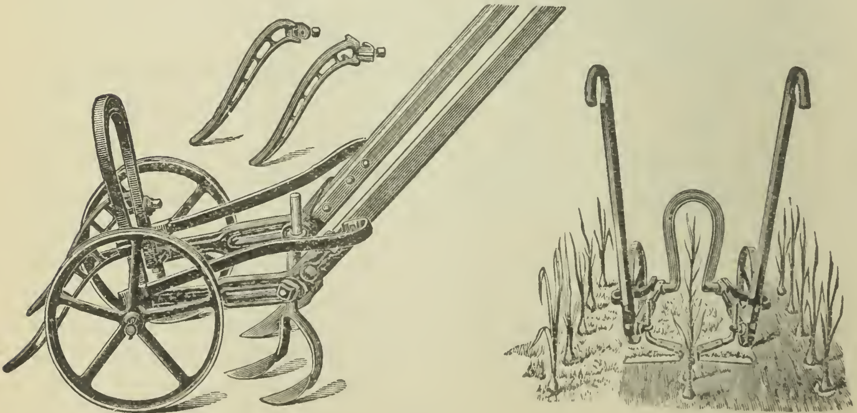

FIG. 5.

When the beets are more advanced a few deeper cultivations may be desirable, and for these any good narrow cultivator may be used for single rows or wider ones for double rows. The instruments shown in Figs. 7 and 8 will be found suitable to this kind of work.*

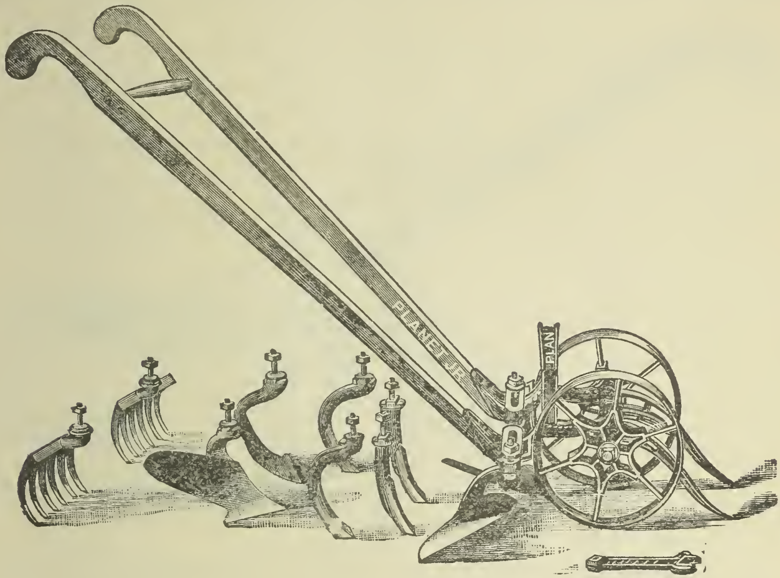

FIG. 6.

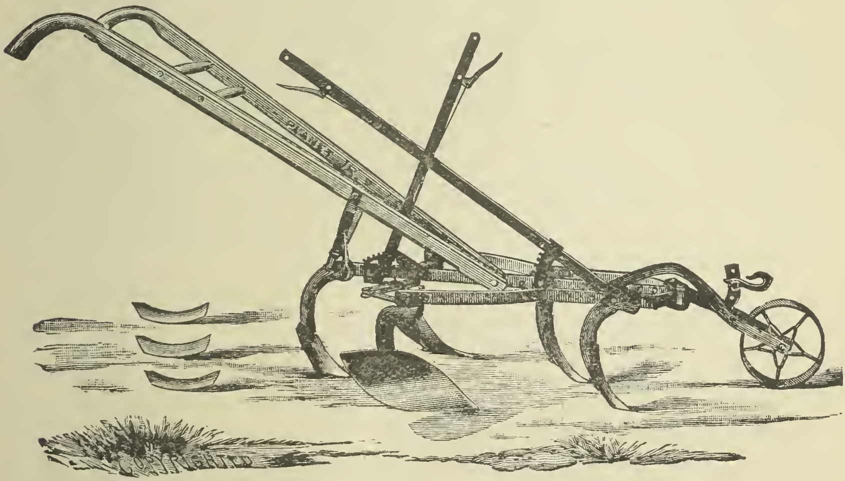

FIG. 7.

The cultivation in all cases should be conducted for the double purpose of keeping the beets entirely free from weeds and for preserving the proper tilth of the surface of the soil. It may be said that at least once a week during the period of growing, lasting from 6 to 8 weeks, the beet field should be cultivated. If the season be very dry, more frequent cultivation will be found useful. The final cultivation should leave the soil practically level. During cultivation care should be taken not to injure either the leaves or the root of the beet, and when the foliage of the growing crop begins to cover well the surface of the soil cultivation may be suspended.

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* Figs. 6, 7, and 8 are from electrotypes furnished by S. L. Allen & Co., of Philadelphia; Figs. 1 and 3, by the Moline Plow Co., and Figs. 2 and 5 by the Deere-Mansur Co.

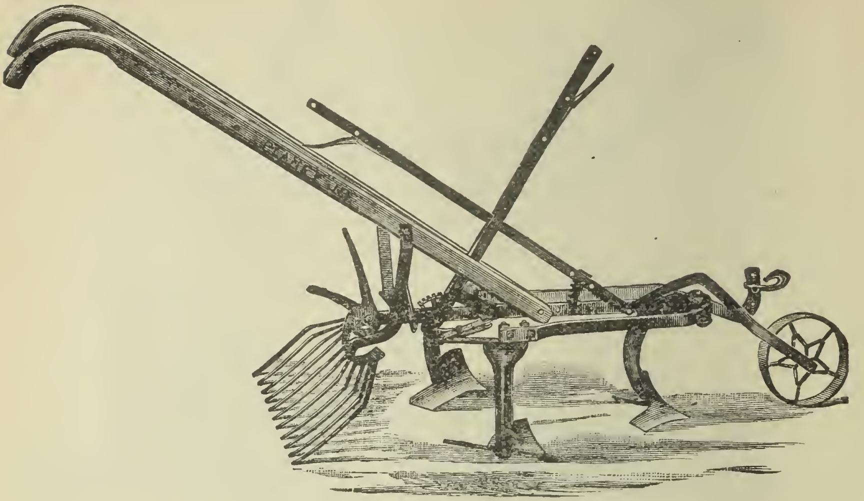

FIG 8

COST OF GROWING BEETS.

The cost of growing an acre of beets depends on so many varying factors as to render it impossible to give an estimate which is reliable for every locality. The differences in rent of land, cost of labor, methods of culture, etc., require that any estimate which may be given should be revised for almost every locality. The following estimate of maximum cost per acre is based on the supposition that land is worth $75 per acre, labor $1 per day, the yield 15 tons per acre, and that the distance to the factory is 1 mile:

Rent of land	$5.00
Plowing, subsoiling, and preparing for planting	5.00
Fertilizers	10.00
Cost of seed	2.25
Planting	1.75
Hoeing and thinning	6.00
Cultivating with horse-hoe five times	5.00
Harvesting	5.00
Topping	12.00
Delivering to factory	7.50
Total	59.50
Value of 15 tons, at $4.50	67.50

In the above estimate has been included the cost of the best culture and a reasonable application of fertilizer. It is probable that the actual cost to our farmers for the first few years of the beet industry will not exceed $45 or $50 per acre. The price paid for the beets is also a minimum. It will not be long before first-class beets, delivered to the factory, will be worth at least $5 per ton.

It is therefore believed that, accidents of season aside, a net profit of from $8 to $15 per acre may be expected from the proper culture of the sugar beet in localities near a factory.

In contrast with the above estimate I give the actual figures submitted by Mr. J. Thomssen, of Hall County, Nebraska, in a letter published in the Prairie Farmer, on the 3d of January, this year. The cost is given for a field of 5 acres; the items are as follows:

Fall plowing, at $1 per acre	$5.00
Plowing in spring, at $1.25	6.25
Rolling twice, once before and once after planting	1.50
Planting by hand, at 75 cents per acre	3.75
Cultivated with hoe, at 75 cents	3.75
Thinning, at $10	50.00
Hoed by hand three times and weeding necessary at time of hoeing	90.00
Cultivated by horse twice, at 75 cents	7.50
Running over with hoe to clear from remaining weeds	3.75
Total	171.50

Dividing this by 5 gives a total of $34.30 per acre.

As will be seen from the above, Mr. Thomssen makes no allowance for the rent of the land, used no fertilizers, and gives no estimate of the expense of harvesting and hauling to the factory. But his field was hoed by hand three times, which with the proper implements is more than is necessary, one good hand hoeing being sufficient.

The average cost per acre of raising sugar beets in France is given in the following detailed estimate from figures furnished by M. E. Du Fay, of Chevry, Cossigny, France:

Farmyard manure	$28.00
Fertilizers	12.00
Spreading manure	.60
Spreading fertilizers	.25
First plowing	1.60
Harrowing and rolling after plow	.64
Plowing and subsoiling	4.60
Two scarifyings	2.00
Two harrowings	.64
Two rollings	.64
Cost of seed	3.00
Sowing of seed	.80
Harrowing and rolling again	.64
Three times hoeing with horse	2.40
Hoeing by hand	4.80
Harvesting by hand	4.00
Harvesting by machine	1.60
Carting to factory	2.40
Total	70.61

To the figures stated are still to be added the rent of land and taxes, $9.40, making a total of $80.01.

The charge for harvesting is very low, from the fact that the topping of the beets is performed by women and children, whose average wages probably do not exceed 15 cents a day, much less than the estimates call for in this country, while the charge for fertilizers is much greater than we should need on our soils for some years to come. The average yield per acre obtained by M. Du Fay is 25 tons, showing the value of intensive farming.

Mr. J. B. Henderson, of Alameda, California, reports the cost of growing and harvesting 10 acres of beets at $614.83, or $61.48 per acre. He was 1 mile from the factory. Mr. A. F. Richardson, of the same place, residing 2 miles from the factory, reports the cost of 11 acres at $535.04 ,or $48.64 per acre.

It is not wise to underestimate the actual cost of growing the beets, for this will lead the farmer to expect large profits which often in practice give way to actual deficits.

HARVESTING.

The time for harvesting varies in different localities. In California it is said that the beets planted in February are ready for harvesting by August. In general it may be said that beets planted the first week in May will be ready for harvesting about the 20th of October. Harvesting should be postponed to as late a date as possible, provided the beets are in no danger of a second growth. The leaves of the ripened beet change from a rich green to a yellowish green, become drooping and applied closely to the earth, and many of them die. The harvesting is best accomplished by first loosening the beets in the soil and then removing them by hand. For loosening the beets, the appara tus shown in Fig. 9 may be employed. It can be used only when the rows are perfectly straight and the beets of a reasonably uniform size. The teeth of the apparatus are sunk deep enough into the earth to catch the beet at about its middle part. The beets are forced back through the teeth of the apparatus, which approach more nearly together in the rear, and on account of the angle at which the teeth are planted, are lifted and the tap roots broken. After the passage of the harvester the beets are easily lifted out by means of their leaves.

The next operation consists in removing the neck. This is done by a large knife and the top of the beet, called technically its neck, is cut off so as to remove, with the top, that portion of the beet to which the stems of the leaves have been attached.

The object of removing this portion of the beet is to prevent the mineral salts, which have accumulated in large quantities therein, from entering the factory. These mineral salts exercise a very deleterious influence on the crystallization of the sugar and, therefore, should be removed. They are well fitted for fertilizing purposes and are of more value when left upon the soil than when removed to the factory.

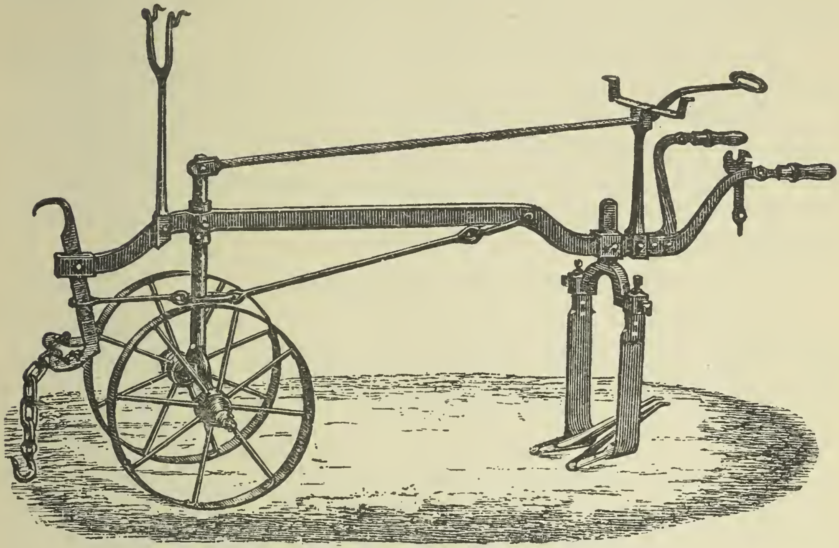

FIG. 9.—Beet harvester for one row.

The removal of the tops of the beets is a tedious process which, in Europe, is performed by women and children. In this country the process of topping the beets will prove much more expensive than in Europe. It is probable that some mechanical device will be invented by which the beets can be topped, thus saving a large expense. So far as we know at the present time, however, this topping must be done by hand.

When the beets are topped they are thrown into piles, and the tops thrown over the beets to protect them from the sun or frost until they can be delivered to the factory.

The beets are best delivered to the factory in dump carts, which permit of their quick unloading. It is not customary for the farmers to silo their beets except in the simple manner indicated above.

SILOING.

When beets are to be preserved for manufacture during the winter months or for the production of seed, they must be carefully protected against frost. The simplest and the easiest method is to place them in piles and cover them with earth, not too deeply, for if they become too warm in the silo they rapidly lose in sugar content. When first siloed, say about the first of November, they should be covered with only a slight layer of earth; as the cold of winter becomes more intense this covering can be increased. In some localities only a slight covering of straw is necessary to protect the beets, as, for instance, in California, and in other localities the deepest covering of earth might not exceed 6 inches, which would be entirely sufficient to preserve the beets from freezing. In other localities, such as in the Dakotas, Minnesota, and Wisconsin, it is probable that the beets would have to be covered to the depth of 2 feet, or even 2 feet and 6 inches, to protect them from frost.

Siloing is usually done by the factory, as it would be very inconvenient to deliver beets from a distance to a factory in the middle of winter.

In most localities in the beet-sugar region of the United States it is probable that the harvesting and delivery to the factory could be entirely completed by the middle of November; although in some seasons there would be no danger whatever in leaving the roots in the earth until the 1st or even the 10th of December.

PRODUCTION OF SEED.

The production of seed is one of the most important operations connected with the sugar-beet industry. On the care and skill which are displayed in this process depend the improvement and maintenance of the sugar-producing qualities of the beet. There are many different methods employed for producing seed which grows the richest sugar beets, but there will be mentioned here only a general outline of the principles which underlie the process. The beets which are to be preserved for seed are called "mothers" and are carefully siloed in the manner already indicated. They are selected at the time of harvesting from specially grown beets or from fields of beets which have shown particularly good qualities on analysis. The size of the roots selected for mothers should be about the average of the best sugar beets, viz , from 20 to 24 ounces. Smaller beets than these would show a higher content of sugar, but it is not wise to produce a race of small beets by selecting the seed from the very smallest and richest beets grown. The size of the mothers having been decided, the beets are next selected for their shape and external appearance. Those regular in shape and smooth in external form are to be preferred. Roots of irregular shape, or with more than one tap-root should be rejected.

The beets to be preserved for mothers are harvested with unusual care to avoid injury. The neck is not cut away, but the leaves are removed by cutting off the stems without injuring the neck of the beet.

The siloing should be of such a nature as to entirely protect the beets from frost and yet prevent their growth in the silo until the spring. The beets are removed from the silo at an early date in the spring and are immediately subjected to analysis for the final selection. In the early days of the beet industry the beets were selected almost solely on account of their specific gravity. A brine of a given strength was made and the beets, thoroughly cleaned of dirt, were thrown into this brine. Those which would sink were selected as mothers while those that would swim were rejected. Selection now depends upon the actual determination of the density of the juice of the beet which is to be selected as a mother and the estimation of its content of sugar. For this purpose a cylindrical or conical piece of the beet is removed, by an appropriate instrument, diagonally through the center of the root. This piece may weigh from 1½ to 2 ounces and its removal does not injure the beet for germinating purposes. The juice is expressed from this piece, and its specific gravity determined by weighing in it, at a given temperature, a silver button of known weight.

The sugar content of the juice is next determined by means of the polariscope. By means of these two data the qualities of the beet for the production of seed are determined and also the coefficient of purity, that is, the number obtained by dividing the percentage of sugar in the juice by its percentage of solid matters as determined by its specific gravity. In mother beets this number should be found somewhere between 80 and 90. The actual method of selection may be illustrated as follows:

The operator determines beforehand his standard, which in most cases will consist of a juice containing 16 to 18 per cent. of sugar, with a purity of 85. The beets are analyzed separately, and are at once divided into two great classes, namely, those in which either the content of sugar or the purity falls below the fixed figure, and, second, those in which these two numbers are equal to or exceed the fixed figures. It is sometimes customary to divide these two classes into two portions, viz., those roots in which the numbers are equal to or slightly above the standard, and, second, those which show exceptional richness. It is also customary to number each beet, and the number, which is cut into the skin of the beet, will remain legible even after the seed has ripened. Some of the producers of sugar-beet seed preserve the product of seed from each beet by itself, and do not use it for the production of seed for commerce until it has received an additional year's trial.

By this method of careful, scientific culture the sugar beet has been raised to its present high standard of excellence, and is only maintained at this standard by constant supervision, such as is indicated.

The sugar beet seed produced by the above method is not sold for planting fields, but is used solely for the production of the seed of commerce in the fourth or fifth year from the parent, as the case may be.

MANUFACTURE OF SUGAR.

The process of making sugar from the sugar beet interests the agriculturist only from secondary considerations, and will be treated of in the briefest possible manner to give an intelligent idea of its methods.

The beets are first conveyed to washing-tanks provided with suitable apparatus for keeping them in motion and transferring them toward the end from which the fresh water enters, in order that the whole of the adhering soil, together with any sand and pebbles, may be completely removed. By a suitable elevator the beets are next taken to a point above the center of the battery, whence they are dropped into a slicing apparatus by which they are sliced into pieces of greater or less length and of small thickness, so that when placed in the cells of the battery they will not lie so closely together as to prevent the circulation of the diffusion juices. The slices, commonly called cossettes, next pass into the diffusion battery in which the sugar is extracted in the usual way. The extracted cossettes are carried through a press by which a portion of the water is removed, and they are then in suitable condition for use as cattle food. The diffusion juices are carried to carbonation or saturation tanks, where they are treated with from 2 to 3 per cent. of their weight of lime and afterward with carbonic acid until nearly all of the lime is precipitated. The slightly alkaline juices are next passed through filter presses by which the precipitated lime and other matter are removed. The juices pass next to a second set of carbonatation tanks in which they undergo a treatment in each particular similar to the one just mentioned, except that the quantity of lime added to the second saturation is very small as compared with that of the first. The refiltered juices from the second saturation are carried to the multiple-effect vacuum-pan and reduced to the condition of sirup. The sirups are taken into the vacuum strike pan and reduced to sugar called masse cuite, containing from 6 to 10 per cent. of water. The uncrystallized sirups together with the water are separated from the sugar by the centrifugals, and form the molasses. The molasses is either reboiled and a second crop of crystals obtained, or is treated in various ways for separating the sugar which it still contains. One of these methods which has come into general use is known as the Steffen process. Another method consists in separating the salts which prevent the crystallization of the sugar by the process of osmosis. A third method consists in the use of strontium salts for the separation instead of lime salts as in the Steffen process; or, finally, the molasses may be subjected to fermentation and distillation and the sugar therein contained thus converted into alcohol.

The above is the general method used for the manufacture of raw sugar. If refined sugar is to be made the juices and sirups are passed over bone-black to decolorize them and the crystals are washed in the centrifugal in order to make them perfectly white Another method consists in treating the juice with sulphurous acid and purifying the crystals by washing them with sirups of varying degrees of consistency until all the molasses adhering thereto is washed away.

The question is often asked if beet sugar can not be made in a small way so that 6 or 7 farmers could club together, put up a cheap apparatus and produce their own sugar. On account of the elaborateness of the process and the costly nature of the machinery which is necessary to produce beet sugar even in a small way, it is not believed that it could be profitably made in the way indicated. A small factory could not possibly compete with a large one and hence there is no encouragement to be offered in the way of producing beet sugar in a small factory. The Department has no knowledge of any successful beet-sugar factory of this kind. There is no country producing any notable quantity of beet sugar in which home apparatus costing only a few thousand dollars have any appreciable influence on the output of sugar. Russia has been cited as an exception to this rule. The output of beet sugar in Russia annually is about 500,000 tons. The total number of factories in operation about 250. The average annual output of each factory in round numbers is 4,000,000 pounds, representing an average consumption of 20,000 tons of beets. From these figures, taken from official data, it is seen that the average size of the Russian beet-sugar factory is not greatly different from those of other European countries.

The waste products of the factory consist of the pulps and molasses. The molasses is used for various purposes; either for fertilizing purposes or for the manufacture of alcohol, or sometimes for cattle food. The pulps make a valuable cattle food. They may be fed in the fresh state or preserved in silos. Lately extensive experiments have been made in drying the pulps and preserving them in the dried state, and these experiments have been fully successful. It is stated that the value of the pulps for feeding purposes is from one-fourth to one-fifth of the value of the beets.

The cost of manufacture depends on as many factors as that of beet growing. Chief among these are transportation, fuel, weather, and labor. Perhaps the most important of these factors is the price of fuel. In some localities coal can be had for $1.25 per ton; in others the cost may reach as high as $10 per ton.

The manufacture of beet sugar is still so much of an experiment in this country as to render any exact account of its cost impossible. To show what it may be, with large experience and the highest skill and management, I give the mean cost of manufacture in 113 German factories from data of the campaign of 1889–'90.

Mean capital invested in each factory		$193,400.00
Total receipts for sugar, molasses, and pulps per ton of beets		11.10
Mean cost of beets per ton of 2,220 pounds	4.90	
Salaries per ton of beets	.26	
Labor per ton of beets	.73	
Interest on investment per ton of beets	.36	
Coal per ton of beets	.63	
Miscellaneous expenses per ton of beets	.96	
Total expense of manufacture per ton		7.84
Profit per ton of beets		3.26

The mean net profit for each factory was $34,240. The price paid for beets, however, is in most cases fictitious, the beet growers owning the factory and preferring to share in the general profits rather than charge a high price for the beets. First-class beets rarely sell for less than $5.25 per ton. The Western Beet Sugar Company of Watsonville, California, stated that in its first campaign, 1888–'89, the cost of making sugar amounted to $80.80 per ton. At the present time it appears that with the best machinery and most economical processes beet sugar can be made in this country at a cost of from 4 to 5 cents per pound.

STATISTICAL.

THE GERMAN CAMPAIGN OF 1888–'9.

During this campaign the new law levying a part of the tax on the beets and a part on the sugar produced came into operation for the first time. The object of this law is to diminish the bounty paid on exports. By the new law the tax on the beets has been reduced to .80 marks per 100 kilograms, instead of 1.7 marks as by the former law. On the other hand, sugars entering consumption pay 12 marks per 100 kilograms, whereas before they paid nothing when made from native beets.

The quality of the beet root harvested in 1888–'89 was much inferior to that of the preceding year, owing to a late, wet spring and an excess of rain in June and July. The yield of sugar was also diminished by early frosts. As the juice of frosted beets was boiled with extreme difficulty, being difficult to filter and granulate, many factories would not accept them.

The following table, according to M. Licht,* gives the actual production of sugar in Germany in metric quintals† and the percentage of yield on the weight of the beet from 1871 to 1889:

Year.	Real production.	Actual yield.	Year.	Real production.	Actual yield.
		Per ct.			*Per ct.*
1871–'72	1,864,419	8.28	1880–'81	5,730,214	9.06
1872–'73	2,625,511	8.25	1881–'82	6,222,885	9.92
1873–'74	2,910,407	8.25	1882–'83	8,489,226	9.71
1874–'75	2,564,124	9.30	1883–'84	9,606,093	10.77
1875–'76	3,580,482	8.60	1884–'85	11,467,303	11.02
1876–'77	2,909,227	8.19	1885–'86	8,381,049	11.85
1877–'78	3,805,091	9.30	1886–'87	10,237,339	12.32
1878–'79	4,301,551	9.35	1887–'88	9,591,184	13.77
1879–'80	4,154,152	8.64	1888–'89	9,904,776	12.55

DEVELOPMENT OF THE CANE AND BEET SUGAR INDUSTRY.‡

The following table expresses in tons of 2,200 pounds the amounts of cane and beet sugar made in the world during the past 7 years:

Year.	Beet.	Cane.	Total.
1883–'84	2,361,000	2,323,000	2,684,000
1884–'85	2,546,000	2,351,000	4,897,000
1885–'86	2,220,000	2,340,000	4,560,000
1886–'87	2,730,000	2,345,000	5,075,000
1887–'88	2,452,000	2,470,000	4,922,000
1888–'89	2,765,000	2,280,000	5,045,000
1889–'90	3,500,000	2,278,000	5,778,000

It is seen from the above table that the production of cane sugar has remained stationary or even diminished during the last septennial period, while the production of beet-sugar has greatly increased.

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*Sugar, April, 1890, p. 46.

† Divide by 10 to get tons of 2,200 pounds each.

‡ La Sucrerie Indigene, March 11, 1890, p. 232.

Willet and Gray (Louisiana Planter and Sugar Manufacturer, April 5, 1890) give the following estimate of the total sugar crop of the world, in tons, for the last 5 years:

Country.	1889-'90.	1888-'89.	1887-'88.	1886-'87.	1885-'86.
Cuba	600, 000	530, 000	610, 000	608, 900	705, 400
Porto Rico	70, 000	55, 000	50, 000	86, 000	64, 000
Trinidad	60, 000	60, 000	60, 000	69, 000	49, 200
Barbadoes	60, 000	50, 000	60, 000	65, 000	44, 000
Jamaica	30, 000	28, 000	30, 000	21, 000	17, 000
Antigua and St. Kitt's	28, 000	25, 000	26, 000	25, 000	25, 000
Martinique	40, 000	38, 000	39, 000	41, 000	33, 000
Guadeloupe	50, 000	45, 000	50, 000	55, 000	37, 000
Demerara	125, 000	108, 000	110, 000	135, 000	111, 800
Reunion	30, 000	25, 000	32, 000	32, 000	35, 000
Mauritius	125, 000	132, 000	120, 000	101, 800	114, 200
Java	310, 000	364, 000	396, 000	363, 950	365, 950
British India	60, 000	60, 000	55, 000	50, 000	50, 000
Brazil	150, 000	220, 000	320, 000	260, 000	186, 000
Manila, Cebu, and Iloilo	180, 000	210, 000	174, 000	180, 000	186, 000
Louisiana	125, 000	145, 000	158, 000	80, 900	127, 900
Peru	30, 000	30, 000	30, 000	26, 000	27, 000
Egypt	35, 000	35, 000	35, 000	50, 000	65, 000
Sandwich Islands	120, 000	120, 000	100, 000	95, 000	96, 500
Total of cane	2, 228, 000	2, 254, 000	2, 465, 000	2, 345, 550	2, 339, 950
Total of beet	3, 550, 000	2, 753, 844	2, 451, 950	2, 730, 206	2, 219, 973
Cane and beet	5, 778, 000	5, 007, 844	4, 916, 950	5, 075, 756	4, 559, 923

La Sucrerie Belge of March 15, 1890, page 372, gives the following estimate of the total production of beet sugar in Europe during the past four years, in tons of 2,200 pounds:

Country.	1889-'90.	1888-'89.	1887-'88.	1886-'87.
Germany	1, 220, 000	978, 000	953, 400	1, 015, 600
Austria	730, 000	514, 000	400, 000	550, 000
France	750, 000	460, 000	420, 000	497, 000
Russia	445, 000	503, 000	430, 000	455, 000
Belgium	172. 000	96, 000	93, 000	91, 000
Holland	55, 000	35, 000	37, 000	36, 000
Denmark	20, 000	19, 000	21, 000	18, 300
Other countries	25, 000	21, 000	14, 000	13, 000
Total	3, 417, 000	2, 626, 000	2, 368, 400	2, 675, 900

STATISTICS OF THE PRODUCTION OF CANE AND BEET SUGAR.

Licht, of Magdeburg, in his last report (Journal des Fabricants de Sucre, March 26, 1890), gives the following figures for the production of beet sugar in Europe for the last three campaigns:

[In tons of 2,200 pounds.]

Country.	1887-'88.	1888-'89.	1889-'90.
Germany	956, 166	990, 604	1, 260, 000
Austria	428, 616	523, 242	750, 000
France	392, 821	466, 767	775, 000
Russia	441, 342	525, 387	475, 000
Belgium	140, 742	145, 804	200, 000
Holland	39, 280	46, 040	60, 000
Other countries	79, 980	87, 000	80, 000
Total	2, 481, 950	2, 784, 844	3, 600, 000

CONSUMPTION OF SUGAR IN THE UNITED STATES.

Imported during the year ending July 1, 1890.

	Pounds.	Value.		Gallons.	Value.
Sugar, duty free	224,457,011	$11,549,828	Molasses:		
Beet sugar, duty paid	601,119,476	18,348,417	Duty free	81,443	$9,314
Cane sugar, duty paid	2,108,435,073	66,196,287	Duty paid	31,415,800	5,168,795
Total	2,934,011,560	96,094,532	Total	31,497,243	5,178,109

Adding to total imports the domestic production, in round numbers 300,000,000 (287,490,271 in Louisiana alone), gives the total sugar in this country for the year ending July 1, 1890, 3,134,011,560 pounds. This number divided by 63,500,000 gives a trifle over 51 pounds per head for the consumption of sugar in the United States. Other estimates make it about 55 pounds per head.

The crop of molasses in Louisiana was 18,431,988 gallons. The production of sorghum and maple molasses and starch sugar sirup can only be estimated, but can safely be put at 30,000,000 gallons, making the total consumption of molasses 79,928,231 gallons.

Consumption of sugar per head for the principal countries during the year 1887.

	Kilogrammes.	Pounds.		Kilogrammes.	Pounds.
Finland	0.60	1.32	German Empire	8.60	18.92
Roumania	1.50	3.30	Belgium	7.14	15.71
Servia	2.00	4.40	Sweden	7.95	17.49
Spain	2.32	5.11	France	12.30	27.06
Italy	3.45	7.59	Switzerland	10.35	22.77
Russia	4.10	9.02	Holland	10.50	23.10
Portugal	4.34	9.55	Denmark	13.47	29.63
Norway	5.16	11.35	Argentine Republic	22.70	49.94
Austria and Hungary	5.50	12.10	Great Britain	32.00	70.40

With free sugar, as provided for by the present tariff, it is estimated that the consumption of sugar in the United States will speedily equal that of Great Britain. At 70 pounds per head, and with a population of 64,000,000, this would amount to 4,480,000,000 pounds annually. It is safe to predict that within 5 years this quantity of sugar will be required for the annual supply of our people. The home market, therefore, for many years to come can not hope to find its supplies in the home product.

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 4.

AGRICULTURAL
EXPERIMENT STATION,
1891
UNIVERSITY OF ILLINOIS.

FUNGOUS DISEASES OF THE GRAPE

AND THEIR TREATMENT,

BY

B. T. GALLOWAY,

CHIEF OF THE DIVISION OF VEGETABLE PATHOLOGY.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1891.

LETTER OF SUBMITTAL.

U. S. Department of Agriculture,
Division of Vegetable Pathology,
Washington, D. C., February 16, 1891.

Sir: I have the honor to submit herewith a bulletin on the treatment of four of our most destructive grape diseases. It is now nearly two years since our last publication on this subject was issued, and during that time many new facts have been brought out. The accompanying pages have been written for the purpose of bringing together these facts in convenient form for the practical grape grower.

Respectfully,

B. T. Galloway,
Chief of the Division of Vegetable Pathology.

Hon. J. M. Rusk,
Secretary.

FARMERS' BULLETINS.

The bulletins of this series may be obtained by applying to the Secretary of Agriculture, Washington, D. C. The following have been previously issued:

Farmers' Bulletin No. 1. The What and Why of Agricultural Experiment Stations. (A brief explanation of the object, origin, and development of the stations, their work in Europe and in the United States, and the operations of the Office of Experiment Stations of the Department of Agriculture.) Prepared by the Office of Experiment Stations. pp. 16. Issued June, 1889.

Farmers' Bulletin No. 2. The Work of the Agricultural Experiment Stations. (Illustrations of Station Work in the following lines: better cows for the dairy; fibrin in milk; bacteria in milk, cream, and butter; silos and silage; alfalfa; and field experiments with fertilizers.) pp. 16. Prepared by the Office of Experiment Stations. Issued June, 1889.

Farmers' Bulletin No. 3. The Culture of the Sugar Beet. (Treats of the climatic conditions, soil, fertilizers, and cultivation required by the sugar beet, cost of growing, time to harvest, and method of siloing; describes briefly the process of beet sugar manufacture, and gives statistics of sugar production and consumption.) By H. W. Wiley, chemist of the Department of Agriculture. pp. 24. Issued March, 1891.

FUNGOUS DISEASES OF THE GRAPE AND THEIR TREATMENT.

GRAPE DISEASES.

There are but four fungous diseases of the grape in this country which occasion sufficient damage to warrant our attention in this bulletin. They are: (1) The grape peronospora or downy mildew; (2) powdery mildew; (3) black rot, and (4) anthracnose. These we shall endeavor to describe in such a way that any one not familiar with them may be able to recognize them and act accordingly.

Grape peronospora or downy mildew, brown rot, and gray rot.—The fungus causing these diseases is known to botanists as *Peronospora viticola.* It attacks the leaves, young wood, flowers, and fruit. On the leaves it usually manifests itself first in the form of greenish yellow or brownish spots on the upper surface, while on the lower side corresponding parts are covered with a white frost-like growth. As the disease progresses the frost-like patches may disappear, leaving only the brown leaf, which soon dries up and falls off. Young wood and flowers are affected in much the same way, but owing to their structure the downy or frost-like stage is more pronounced. This form of the disease is known as the downy mildew, and in some sections it causes the only serious damage. On the fruit the fungus occurs in two forms, causing what is known as brown and gray rot. The former disease as a rule does not make its appearance until the berries are nearly grown. At this time a brownish purple spot will appear on one side of the berry and in a short time the whole fruit is involved, turning brown and ultimately becoming soft and wrinkled. The skin usually remains unbroken until the berry drops to the ground, which it does at the slightest touch or jar. In gray rot the fruit is covered with the same frost-like growth seen on the leaves. The berries are literally plastered together with the fungus, the effect being so peculiar and so different from any other disease that no one will fail to recognize it.

Powdery mildew.—This usually appears about midsummer, attacking the leaves, young wood, and berries. Occasionally, however, it appears earlier in the season and in such cases is often very destructive to the flowers. It forms on the various parts attacked a powdery mealy growth, this being very marked on the leaves, where it is usually more abundant upon the upper surface. The berries attacked often crack, exposing the seed in a very peculiar manner. Upon close examination of any part of the vine affected with powdery mildew fine delicate threads which make up the vegetative portion of the fungus may be seen. This in itself is enough to distinguish the disease from downy mildew, the only malady for which it is likely to be mistaken.

Black rot.—Black rot is so widespread and well known that it is hardly necessary to describe it. It may be well, however, to call attention to the fact that the disease usually appears first on the leaves and young shoots, causing reddish brown or blackish spots. Ten or 15 days later the berries are attacked, the first evidence of this being a black or brownish spot at one or more points on the surface. Soon the whole berry turns brown, then black, and finally becomes hard and leathery, but as a rule clings firmly to its stalk.

Anthracnose.—Like the downy mildew and black rot, anthracnose attacks the leaves, growing shoots, and young berries.

Leaves, when first affected with the disease, show minute blackish brown spots, which are surrounded with a slightly raised, darker-colored margin. Ultimately the centers of the spots turn gray, and not infrequently the diseased parts crack across or separate from the surrounding healthy portions, leaving the leaf full of small, ragged holes. On the shoots, the disease manifests itself in much the same way as it does on the leaves. As it progresses, however, the spots usually become darker at their center, and often run together, forming more or less elongated diseased areas which gradually eat their way into the wood. The scars made in this way may often be seen on the ripened wood, and it is now known that the mycelium or body of the fungus passes the winter in the tissues surrounding these places.

Anthracnose on the fruit, or bird's-eye rot, as it is sometimes called, first appears as a blackish or brown circular spot surrounded by a narrow, somewhat darker rim. As the spots increase in size the color undergoes various changes. In some cases the outside rim remains dark brown, while inside of this is a wider zone of a beautiful vermillion color surrounding a grayish center. Frequently the spots, when less than one-eighth of an inch in diameter, assume a grayish-white color, which they retain throughout the rest of their growth. When the berries are small the disease often manifests itself in another way. The fruit turns brown, shrivels up, and, at the same time, little pinkish pustules appear on the surface. The grape may also develop unequally, the affected side being flattened.

This form of rot is not characterized by a softening of the tissues, as in the case with others we have mentioned. The tissues slowly collapse, but at the same time become hard and wrinkled.*

Believing that the foregoing remarks will, after a little study, enable anyone to recognize these various diseases, we will next direct our attention to the remedies and their preparation.

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* Circular No. 7.

REMEDIES AND THEIR PREPARATION.

Experience has shown that for all practical purposes there are but four fungicides worthy of consideration in this connection: (1) The simple solution of copper sulphate; (2) the Bordeaux mixture; (3) the ammoniacal solution of copper carbonate; and (4) eau celeste. Of course there are other preparations which bid fair to be fully as valuable as any of the preceding, but as yet we do not know enough about them to recommend their extended use unqualifiedly.

(1) *Simple solution of copper sulphate.*—This is prepared in the usual way by simply dissolving 1 pound of the copper sulphate in 25 gallons of water.

(2) *Bordeaux mixture.*—The only formula now generally used is that containing 6 pounds of copper sulphate and 4 pounds of lime to 22 gallons of water. For many reasons we find it advantageous to use powdered copper; still, when time is not an important element, the crystals answer just as well and, as a rule, are from 2 to 3 cents cheaper per pound. In our work we usually provide ourselves with three barrels, one of which we divide in the middle, making two tubs holding 22 gallons. One of the barrels we use for water, which is obtained at the nearest well, clear stream, or pond. Twelve pounds of copper sulphate are weighed out and placed in one of the tubs, 6 or 7 gallons of water are added and the copper stirred in this until the water is blue. This blue solution is then poured into the empty barrel and 6 or 7 gallons more of water are poured into the tub containing the copper and the latter is stirred as before. This process is repeated until all of the copper is dissolved, it being found that 16 or 20 gallons of water are necessary for this purpose, providing crystals are used and the water is cold. Powdered copper sulphate requires much less labor and water to dissolve it, and for this reason we prefer it to the crystals. All of the copper being dissolved, 8 pounds of lime are slacked in one of the tubs. After slacking, enough water is added to make a rather thin whitewash, then this is poured slowly into the barrel containing the copper solution. We usually strain the whitewash through a coarse gunny sack, having the latter stretched over the head of the barrel. The straining removes all of the small pieces of lime, sticks, straws, etc., which have a tendency to clog the nozzle. After pouring in all the whitewash, more water is added until the barrel is filled to within 5 inches of the top. The solution is then thoroughly stirred, when it is ready for use.

Of course, the above process can be variously modified as occasion may require. Instead of hauling the water to the vineyard it may be found more convenient to prepare the mixture near the water supply and then convey it where it is to be used either in barrels or tanks made for the purpose.

In one or two parts of the country, notably central Virginia, it is claimed that Bordeaux mixture of the above strength is apt to injure the foliage of some varieties, especially Norton's Virginia. The only way we can account for this is that the soil and climate of these regions is such as to render the vines more susceptible to the action of fungicides, or else that proper care is not exercised in the use of these preparations. It is more likely, however, that the trouble is due to climatic influences, and if this is the case it becomes necessary to reduce the amount of copper somewhat. Around Charlottesville, Va., grape growers are using a formula containing from 2 to 3 pounds of copper sulphate and 1½ to 2 pounds of lime to 22 gallons of water very successfully. We would not recommend the use of this formula excepting in the very rare cases where the vines appear to be injured by the stronger mixture. In this connection it might be well to say that injury has sometimes resulted to the vines from the use of the Bordeaux mixture made with air slaked lime. In all cases it is best to use *fresh* lime, but when this can not be readily obtained it would be well to use 5 or 6 pounds of the air slaked for each 6 pounds of copper.

(3) *Ammoniacal solution of copper carbonate.*—(*a*) In an ordinary water pail dissolve 5 ounces of copper carbonate in 3 pints of aqua ammonia, having a strength of 26°. If 3 pints of ammonia are not sufficient to completely dissolve the copper, add enough to bring about this result. When completely dissolved pour the solution into a barrel and fill the latter with water.

Ammoniacal solution of copper carbonate.—(*b*) Mix thoroughly 6 ounces of pulverized ammonia carbonate and 1 ounce of copper carbonate. Keep in an air-tight vessel, and when ready for use dissolve in 10 gallons of water.

This preparation is not as expensive as the preceding; moreover it has other advantages, namely, ease of preparation, portability, etc. When only a few acres are to be treated the chemicals might be obtained ready mixed, put up in air tight cans. A 5 pound can, sufficient for 100 gallons of the solution, put up in this way should not cost over 50 cents. Buying the chemicals in quantity and mixing them at home will reduce the expense considerably. A further reduction will result if the copper carbonate is made at home according to directions which are given further on.

(4) *Eau celeste.*—Dissolve 2 pounds of copper sulphate in 6 or 8 gallons of water. When thoroughly dissolved add 3 pints of strong ammonia and dilute to 50 gallons. Last season we prepared and sent out a mixture for trial which, in some cases, gave very good results, so far as its fungicidal properties were concerned. It has the same objection as eau celeste, namely, that it is not safe to use it on tender foliage. The mixture consists of equal parts of ammoniated copper sulphate and ammonia carbonate. It was put up in air-tight cans, and for use was simply dissolved in water at the rate of 1 pound to 25 gallons. The solution thus obtained is practically the same as eau celeste made in the usual way. One pound of the mixture costs 45 cents, making it more expensive than eau celeste prepared according to the old formula.

The only advantage the mixture possesses is that it enables those who may wish to use the eau celeste in small quantities to do so without going to the trouble of buying the copper sulphate, aqua ammonia, etc., and mixing them.

(5) *Eau celeste, modified formula.*—Dissolve 4 pounds of copper sulphate in 10 or 12 gallons of water. Add 3 pints of strong ammonia, dilute to 50 gallons, and add 5 pounds of common washing soda. Stir thoroughly and the solution is ready for use.

This is one of the oldest fungicides, having been used first in 1887.* It rarely injures the foliage, and for this reason is much more desirable than the simple eau celeste. The ammoniacal solution has, however, about superseded these preparations in the treatment of nearly all plant diseases.

Convenient measures.—It is often inconvenient to take scales into the field; moreover, when they are at hand it requires considerable time to weigh out the various chemicals used. If the following facts are remembered it will frequently save time and trouble:

	Quarts.
6 pounds of copper sulphate, crystals	2¼
6 pounds of copper sulphate, powdered	2
4 pounds of lime, unslaked, in pieces the size of pigeons' eggs	2½
4 pounds of lime, slaked	3

A convenient measure for the copper carbonate may be made from a baking-powder can or something similar. First weigh the can, then put in 5 ounces of the chemical and mark the place. We have 1-ounce, 2-ounce and 5-ounce cans made in this way and find them exceedingly useful and labor-saving.

Manufacturing copper carbonate.—In this connection, and before proceeding with the directions for treatment, it may be well to call attention to the fact that if desirable the copper carbonate can be manufactured at home at about one-third the price usually charged for it in the wholesale markets. Following are directions for manufacturing it:

In a tub or barrel dissolve 6 pounds of copper sulphate in hot water. In another suitable vessel dissolve 7 pounds of sal soda in hot water. When the two solutions are cool, pour the second slowly into the first, then add water until the tub or half-barrel is full. Stir the solution thoroughly and let it stand for 24 hours, then siphon off the clear liquid and add fresh water. Stir again, and again allow the solution to stand 24 hours; siphon off the clear liquid as before, then remove and dry the sediment, which is carbonate of copper. Using the above quantities of copper sulphate and sal soda there will be formed 3 pounds of copper carbonate. Sal soda sells at wholesale for 1½ cents per pound, so that on this basis the necessary chemicals to make 3 pounds of copper carbonate will cost 46½ cents, or 15½ cents for 1 pound. The usual wholesale price for this chemical is 40 cents per pound.

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* Circular No. 5.

TREATMENTS.

Downy mildew, brown and gray rot.—Use either the ammoniacal copper carbonate solution, eau celeste, or the Bordeaux mixture, preferably the first on account of its being cheaper and not so likely to injure the foliage. Make the first application about the time the berries are well formed, which, as a rule, is 10 or 12 days in advance of the mildew. Repeat the sprayings every 12 or 15 days, or more often if there are frequent heavy rains, until the berries begin to color. In some sections where the mildew is unusually severe it may prove advantageous to make one or two sprayings after the fruit is harvested in order to insure perfect ripening of the wood.

Eau celeste is now largely used in the treatment of this disease in northern Ohio, especially on the islands of Lake Erie. In this climate it does not seem to injure the foliage at all, but this can not be said of any other section so far as we know.

Powdery mildew.—The fungus causing this disease succumbs readily to treatment with any of the copper compounds.* Where the disease exists alone we would recommend the use of the ammoniacal copper carbonate solution. In regions where the mildew is common the vines should be carefully watched, and at the first sign of the trouble, applications should begin and be repeated at intervals of 12 or 15 days. Excepting on the Pacific coast, there are comparatively few regions where this disease exists alone, and of course where it is associated with any of the other maladies mentioned in this paper one treatment will answer for all.

Black rot.—Four general methods of treating this disease are now practiced by us, as follows:

(1) In spring, after the vines have been pruned and before the buds begin to swell, spray the wood with the simple solution of copper sulphate. About the time the leaves are one-third grown apply the Bordeaux mixture. Repeat the latter treatment when the vines are in full bloom and thereafter at intervals of 10 or 12 days until the fruit begins to ripen.

(2) Omit the spraying with the simple solution, but for the rest follow the rules laid down in No. 1.

(3) Treat exactly the same as No. 2, except use the ammoniacal solution instead of the Bordeaux mixture.

(4) For the two first treatments apply the Bordeaux mixture the same as in No. 2, then for the rest of the season use only the ammoniacal copper carbonate solution.

In regard to these various methods it may be said that No. 1 is objectionable on account of the additional cost of the treatment with the simple solution. In the majority of cases it is doubtful if these early applications do any real good; still, in an old vineyard which has never been treated, it may prove beneficial by destroying many of the dormant spores. Method 2 is probably the most reliable of all, as it has stood the test of several seasons and has never failed us, no matter how favorable the weather is for black rot and other diseases. It is more expensive than either No. 3 or No. 4, moreover the mixture by spotting the fruit may render it unfit for market. The plan outlined under No. 3 last season gave fully as good results as any of the others. It possesses the advantage of being cheap and requires no special apparatus to carry it out. The last method, or No. 4, has no particular advantages over the others unless it be that it allows the use of the Bordeaux mixture at a critical period without danger of spotting the fruit. All things considered we should advocate for an ordinary season either No. 3 or No. 4, but if heavy rains are frequent we would recommend that the Bordeaux mixture alone be used.

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* This does not refer to Vinifera stock.

Anthracnose.—This disease rarely occurs alone. As a rule it is found associated either with black rot or mildew, and when this is the case no additional treatment can, in the present condition of our knowledge, be recommended. For anthracnose alone the only remedy that has given any beneficial results is the Bordeaux mixture, applied in the same manner as recommended for black rot.

General treatment.—In many parts of the country it is a common thing to find downy mildew, black rot, and anthracnose all working together. In such cases the question has arisen as to whether we could not devise some general treatment which would hold all of these maladies in check. Experience has shown that any of the treatments recommended for black rot will do this providing the anthracnose is not unusually severe.

METHODS OF APPLYING THE REMEDIES.

It is of the utmost importance that the remedies reach all the green parts of the vine. These do not need to be drenched; on the contrary they only require a thin film of the fungicide to protect them against infection. It is only possible to obtain this even distribution by means of careful work and the use of suitable spraying pumps and nozzles. It is next to useless to resort to watering cans and old brooms as many do, although this treatment is perhaps better than none at all. At the present time every gardener, farmer, and fruit grower should own a spraying machine of some kind. There are so many in the market and they can be obtained so readily that it is useless to mention any particular styles. Where one has only a few vines one of the ordinary brass syringes sold by florists for $1.50 will answer. For medium-sized vineyards, *i. e.*, 10 to 20 acres, the knapsack* form of pump provided with spraying nozzles is a most excellent machine. These pumps are now largely used in vineyards where the ground is uneven or where it is difficult to get in with the large horse-power machines. The prices of these pumps complete range from $14 to $25; they are sold now by nearly all reputable agricultural implement dealers. For large vineyards where the ground is level large machines may be used. Machines of this kind are made which will spray an acre in 30 minutes, requiring the labor of two men, two horses and a boy to manage them.

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* For full description with working drawings of a knapsack pump and spraying nozzles see Journal of Mycology, Vol. 6, No. 11.

A very convenient machine suitable for large vineyards can be rigged up at home, the materials necessary being a barrel, a strong force pump having two discharge pipes, two pieces of three-quarter-inch hose each 16 feet long, and two spraying nozzles. This outfit complete need not cost over $15. The apparatus is placed in a wagon or cart, which is drawn by a horse. A boy manages the horse while one man remains in the wagon or cart and works the pump; two more men follow behind using the nozzles and spraying two rows at a time. When such a machine as this is used it will keep two men busy preparing the fungicide.

COST OF THE TREATMENTS.

The cost of the treatments will depend in a large measure upon the kind of spraying apparatus used and prices paid for chemicals. With a good spraying machine and chemicals obtained at wholesale figures it is safe to estimate the total cost of treating, say an acre of bearing grapes with the principal remedies six times, as follows:

		Cents.
Bordeaux mixture	per vine..	3
Ammoniacal solution	do....	2
Bordeaux mixture, two sprayings; ammoniacal solution, four sprayings	do....	2½
Additional expense of spraying with simple solution of copper sulphate	do....	⅓

These figures are based upon the fact that the chemicals are purchased at the following usual wholesale prices:

		Cents.
Copper sulphate, crystals	per pound..	6
Copper carbonate	do....	40
Aqua ammonia, 26°	do....	8
Ammonia carbonate	do....	11
Lime	per bushel..	30

It requires on an average 3 quarts of liquid per vine for the season's work of six applications. Taking the foregoing as a basis, we will, to be more explicit, estimate the cost of treating an acre of bearing vines, assuming that the rows are 10 feet apart and the vines are 8 feet apart in the row. This will give us 544 vines to the acre. Multiplying 544 by ¾ will give us 408, the number of gallons required to treat an acre. Four hundred and eight gallons of the Bordeaux mixture will cost as follows:

Copper sulphate, 111 pounds, at 6 cents	$6.66
Lime, 74 pounds	.50
Total	$7.16

With an ordinary knapsack sprayer it will require about 92 hours of labor to make six applications in the proper manner. Estimating this labor at 10 cents an hour we have $9.20. Adding this to the cost of chemicals brings the total up to $16.36. This amount divided by 544, the number of vines to the acre, gives practically 3 cents. These figures, we believe, will enable any one to answer such questions as may arise in connection with this part of the subject, taking it for granted that the labor for each liquid is the same.

CONCLUDING REMARKS.

Under this heading we wish to call special attention to the importance of early treatment, and the absolute necessity of always bearing in mind that the work is wholly preventive. The man who waits until the mildew or black rot has a fair start in his vineyard, before beginning the fight, might probably just as well pour his fungicides on the ground for all the good it will do his vines.

There is no longer any question as to the efficacy of these treatments, as is evidenced by the fact that thousands of grape-growers are now adopting them, and are saving in consequence all the way from 50 to 90 per cent of their crop. As the matter now stands, success rests wholly with the one who plans and carries on the work.

One other matter in this connection seems worthy of attention, and that is this: It should be the aim of every fruit grower to keep his plants in health whether they are bearing fruit or not. If they do not bear fruit this year they will in all probability do so the next. For this purpose it is necessary that they shall have stored up sufficient material to properly mature the fruit, and this is made possible only by the presence of vigorous, healthy foliage. Spray, therefore, if it will save the foliage, for there is no doubt that the little expended in this way will, in the end, yield a handsome profit.

PUBLICATIONS OF THE DIVISION OF VEGETABLE PATHOLOGY.

Frequent requests are received for bulletins of this Division which are out of print. The following list includes all the publications issued to date. Those still on hand for distribution are indicated by an asterisk (*). It will be seen that in this series Numbers 1, 3, 4, and 6 are missing. These represent bulletins of the Botanical Division.

1. Bulletin No. 2. Fungous Diseases of the Grape. 1886, pp. 136, pl. 7.
2. Bulletin No. 5. Report on the experiments made in 1887 in the Treatment of Downy Mildew and Black Rot of the Grape. 1888, pp. 113.
3. Bulletin No. 7. Black Rot. 1888, pp. 29, pl. 1.
4. Bulletin No. 8. A record of Some of the Work of the Division. 1889, pp. 69.
5. Bulletin No. 9. Peach Yellows. 1889, pp. 254, pl. 36.
6. Bulletin No. 10. Report on the Experiments made in 1888 in the Treatment of Downy Mildew and Black Rot of the Grape, pp. 61.

7. Bulletin No. 11.* Report on the Experiments made in 1889 in the Treatment of Fungous Diseases of Plants. 1890, pp. 119.
8. Journal of Mycology, Vol. 5, Nos. 1, 2, 3 and 4, 1889, pp. 249, pl. 14.
9. Journal of Mycology, Vol. 6, Nos. 1, 2,* and 3,* 1890, pp. 135, pl. 6.
10. Circular No. 1. Treatment of Downy Mildew and Black Rot of the Grape. 1885, pp. 3.
11. Circular No. 2. Grape Vine Mildew and Black Rot. 1885, pp. 3.
12. Circular No. 3. Treatment of Grape Rot and Mildew. 1886, pp. 2.
13. Circular No. 4. Treatment of the Potato for Blight and Rot. 1886, pp. 3.
14. Circular No. 5. Fungicides or Remedies for Plant Diseases. 1888, pp. 10.
15. Circular No. 6.* Treatment of Black Rot of the Grape. 1888, pp. 3.
16. Circular No. 7.* Grape Vine Diseases. 1889, pp. 4.
17. Circular No. 8.* Experiments in the Treatment of Pear Leaf Blight and Apple Powdery Mildew, pp. 11.
18. Circular No. 9. Root Rot of Cotton. 1889, pp. 4.

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U. S. DEPARTMENT OF AGRICULTURE.
DIVISION OF VEGETABLE PATHOLOGY.

FARMERS' BULLETIN No. 5.

TREATMENT

OF

SMUTS OF OATS AND WHEAT.

AGRICULTURAL EXPERIMENT STATION,
FEB 11 1893
UNIVERSITY OF ILLINOIS.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1892.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF VEGETABLE PATHOLOGY,
Washington, D. C., February 16, 1891.

SIR: I have the honor to transmit herewith a Farmers' Bulletin on the treatment of smuts of oats and wheat. This bulletin has been prepared under my direction by Mr. W. T. Swingle, an assistant in the Division, who for a number of years has devoted special attention to smut diseases. The object of the bulletin is to place before the farmers, in concise form, the results of recent experiments made in this country and Europe in the treatment of smuts.

Respectfully,

B. T. GALLOWAY,
Chief of Division

Hon. J. M. RUSK,
Secretary.

FARMERS' BULLETINS.

The bulletins of this series may be obtained by applying to the Secretary of Agriculture, Washington, D. C. The following have been previously issued:

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TREATMENT OF SMUTS OF OATS AND WHEAT.

BY W. T. SWINGLE.

Smuts are minute parasitic plants belonging to the great group fungi. By their action they cause diseases of higher plants. The two smuts which cause the greatest damage in the United States, and which for this reason will be chiefly considered here, are the loose smut of oats and the stinking smuts of wheat. It is hoped that the following brief descriptions will enable any one to recognize them.

THE LOOSE SMUT OF OATS.

In case of the loose smut of oats the grains and usually the husks are transformed into a black powdery mass consisting of the spores of the fungus intermixed with a few shreds of tissue of the plant itself. The oat plants first show signs of the disease at the time of heading out, when, instead of a normal head, a smutted one is produced. The smut becomes fully mature at the time of blossoming of the oats and is then easily scattered by the winds. By harvest time the smut has often been entirely blown away, leaving only the naked and stalk remaining. The fungus is known to botanists as *Ustilago avenae* (Pers.) Jensen. In Plate I Fig. 1 shows a large smutted head, the husks of which are only partially destroyed by smut; Fig. 2, a fully smutted head; and Fig. 3, a fully smutted head as it appears at harvest time with nearly all the smut blown away.

THE STINKING SMUT OF WHEAT.

This smut, unlike that of oats, attacks only the grain. In consequence the heads have nearly their normal appearance. Upon close examination the grains are seen to be swollen, of a greenish color at first, but finally brown or gray. If one of these swollen smutted grains be crushed it will be found to be filled with a dull brownish powder which has a very penetrating and disagreeable odor. The presence of this odor, which has given rise to the common name, is a very good test for the presence of the smut. The smut is due to either of two very nearly identical fungi, *Tilletia foetens* (B. & C.) Schroet. and *T. tritici* (Bj.) Wint. Figs. 4 and 5 of the plate show smutted heads of awned wheat and beardless wheat respectively.

AMOUNT OF DAMAGE.

The amount of damage caused by the loose smut of oats is very rarely fully appreciated. Wherever careful investigations have been made the per cent of heads attacked by smut has been found to be considerable. The average loss is from 5 to 12 per cent in different localities in the United States. The percentage of smutted heads also varies in a given locality in different years. Usually the smut is not noticed at all unless it is very abundant, for by harvest time most of the smut has fallen from the diseased heads, leaving often only the bare and inconspicuous stalks. The question will no doubt be asked: Will it pay to treat the oats for seed when only 5 or even 10 per cent of the heads are smutted? It may be said in answer that the per cent of heads destroyed by smut does not represent the amount that will be recovered by treating the seed. In all the careful experiments made with the methods of seed treatment described below there has been found to be an *extra increase* beyond and above the amount that would naturally be expected by replacing smutted heads with sound ones. This extra increase is found to range from one to ten times the amount of direct damage resulting from the loss of the smutted heads. Besides this gain there is that arising from the fact that the oats raised from treated seed *will produce a crop free from smut*, if there are no smutty oats in neighboring fields. Taking all these facts into consideration it is highly probable that it will be found profitable to treat seed oats if they come from a field showing more than 1 per cent of smutted heads, and it will certainly pay to treat the seed if it came from a field showing more than 3 per cent of smutted heads. It is a fair estimate based on counts made in many parts of the Union to estimate the *net gain* to be obtained by treating seed oats at 8 per cent of the crop obtained. Since the aggregate value of the oat crop of the United States from 1880 to 1890 was $2,030,712,605,* the net gain from a universal system of seed treatment would have been $162,457,008.40 for those years.

Every farmer who raises oats is strongly urged to treat the seed unless, upon careful counts made in different parts of the field, there are found to be less than three heads out of every hundred smutted. Above all, do not conclude that because you have not noticed any considerable amount of smut in your fields it will not pay to treat the seed. The safer method would be to treat the seed, unless the field from which it was obtained is known to be free from the smut. It should also be remembered that the gain is just as real even if oats are not a paying crop, or even if merely grown for straw, for there is found to be an increase in the weight of straw grown from treated oats.

The stinking smut of wheat is unfortunately too well known and too much feared by both farmers and millers to need here any recital of the damage it causes. Suffice it to say that when once introduced it usually

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*Dodge, J. R. Report of the Statistician, in Report of the Secretary of Agriculture, 1890, p. 301.

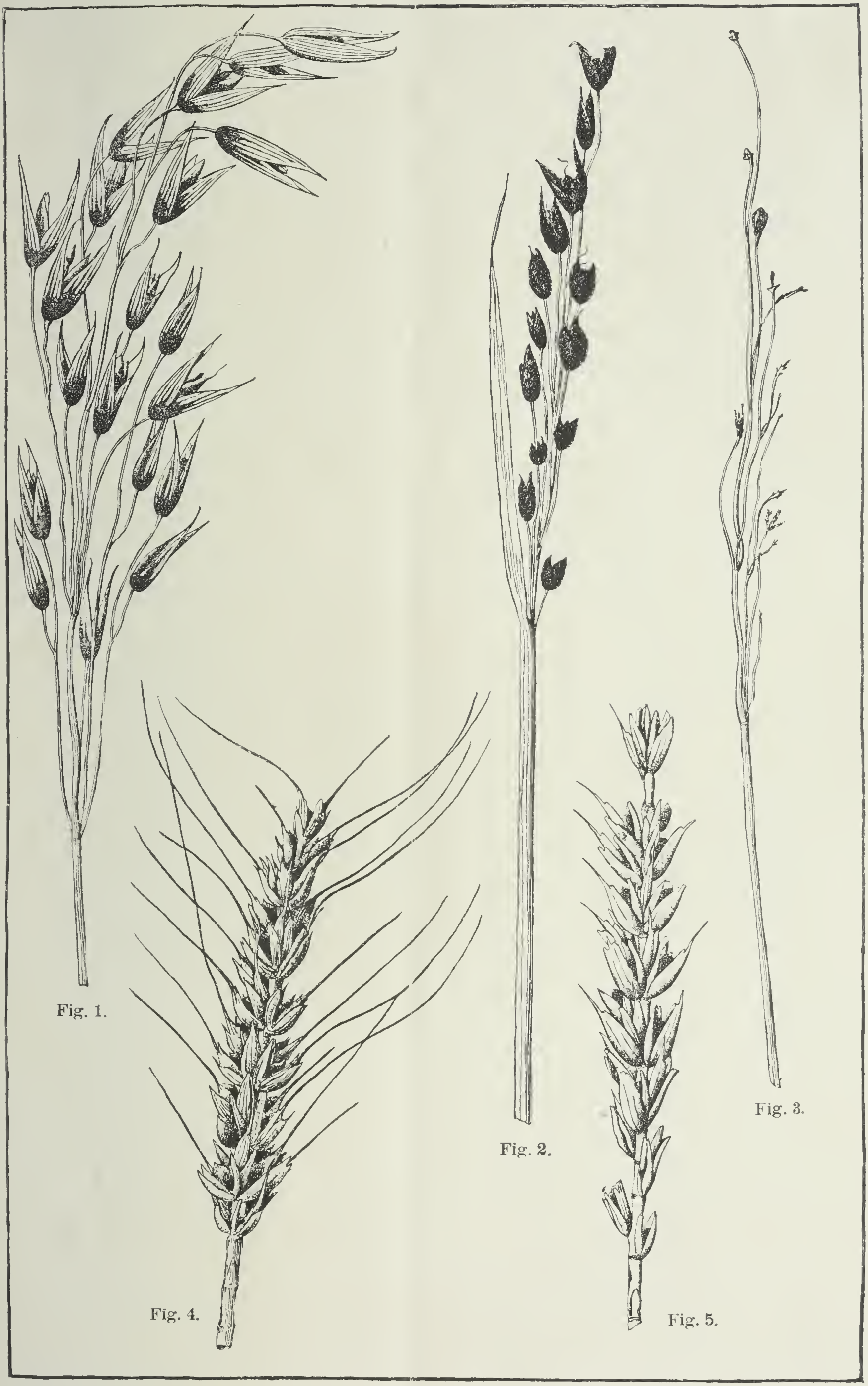
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.

SMUTS OF OATS AND WHEAT.

increases year by year, until often 40 to 60 per cent of the grain is destroyed. Besides this, the remaining portion is rendered unsalable as well as unfit for seed. Farmers do not need to be urged to treat the seed to prevent this smut, as they are only too glad to learn of any certain method of preventing the ravages of this foe. As the smutted grain is easily recognized by the odor, and as it is absent altogether from many parts of the country, it will be wiser not to treat the wheat for seed unless the smut is known to be present.

OTHER SMUTS.

Loose smut of wheat.—In addition to the stinking smut, wheat is also subject to a loose smut much like that of oats, and, like that, without odor. As yet no method of combating it can be recommended. The loose smut of wheat is caused by *Ustilago tritici* (Pers.) Jens.

Barley smuts.—Barley is subject to two loose smuts, both somewhat like oat smut. They may be prevented by soaking the seed barley four hours in cold water, letting it stand four hours in a moist state in sacks, and finally treating in hot water as directed for oats and wheat, but only for five minutes and at a temperature of 126° to 128° F.

HOW TO PREVENT OAT AND WHEAT SMUT.

It has been found that the infection of the plant takes place when the seed is germinating and from spores adhering to the seed when planted. If these adhering spores can be killed a crop wholly free from smut can be obtained.*

The Jensen or hot-water treatment for oat and wheat smut.—This method, discovered by J. L. Jensen, of Denmark, in 1887, consists in immersing the seed which is supposed to be infected with smut for a few minutes in scalding water. The temperature must be such as to kill the smut spores, and the immersion must not be prolonged so that the heat would injure the germinative power of the seed. If the water is at a temperature of 132½° F., the spores will be killed, and yet the immersion, if not continued beyond fifteen minutes, will not in the least injure the seed. The temperature must be allowed to vary but little from 132½°, in no case rising higher than 135°, or falling below 130°. To insure these conditions when treating large quantities of seed, the following suggestions are offered:

Provide two large vessels—as two kettles over a fire, or boilers on a cook stove, the first containing warm water (say 110° to 130°), the second containing scalding water (132½°).

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*There is some good evidence to show that fresh manure of herbivorous animals containing smut spores may, if applied at the time of planting, infect the young plants. It is hardly necessary to mention this manner of infection, since almost no American farmers manure grain fields in this manner. There is no danger in using well rotted manure.

The first is for the purpose of warming the seed preparatory to dipping it into the second. Unless this precaution is taken it will be difficult to keep the water in the second vessel at a proper temperature.

The seed which is to be treated must be placed, a half bushel or more at a time, in a closed vessel that will allow free entrance and exit of water on all sides. For this purpose a bushel basket made of heavy wire could be used, with which spread wire netting, say 12 meshes to the inch, or an iron frame could be made at a trifling cost, over which the wire netting could be stretched. This would allow the water to pass freely and yet prevent the passage of the seed. A sack made of loosely woven material (as gunny sack) could perhaps be used instead of the wire basket. A perforated tin vessel is in some respects preferable to any of the above.

Now dip the basket of seed in the first vessel; after a moment lift it; and, when the water has for the most part escaped, plunge it into the water again, repeating the operation several times. The object of the lifting and plunging, to which should be added also a rotary motion, is to bring every grain in contact with the hot water. Less than a minute is required for this preparatory treatment, after which plunge the basket of seed into the second vessel. If the thermometer indicates that the temperature of the water is falling, pour in hot water until it is elevated to 132½°. If it should rise higher than 132°, add small quantities of cold water. This will doubtless be the most simple method of keeping the proper temperature and requires only the addition of two small vessels, one for cold and one for boiling water.

Steam, conducted into the second vessel by a pipe provided with a stopcock, answers even better, both for heating the water and elevating the temperature from time to time.

The basket of seed should, very shortly after its immersion, be lifted and then plunged and agitated in the manner described above; and the operation should be repeated eight or ten times during the immersion, which should be continued fifteen minutes. In this way every portion of the seed will be subjected to the action of the scalding water. Immediately after its removal dash cold water over it or plunge it into a vessel of cold water and then spread out to dry. Another portion can be treated similarly, and so on until all the seed has been disinfected. Before thoroughly dry the seed can be sown; but it may be thoroughly dried and stored if desired.

The important precautions to be taken are as follows: (1) *Maintain the proper temperature* of the water (132½° F.), in no case allowing it to rise higher than 135° or to fall below 130°. This will not be difficult to do if a *reliable thermometer* is used and hot or cold water be dipped into the vessel as the falling or rising temperature demands. Immersion fifteen minutes will not then injure the seed. (2) See that the volume of scalding water is much greater (at least six or eight times) than that of the seed treated at any one time. (3) Never fill the basket or sack containing the seed entirely full, but always leave room for the grain to move about freely. (4) Leave the seed in the second vessel of water *fifteen minutes.*

The hot-water treatment for oats.—The foregoing method is applicable to both wheat and oats. With oats the following slight modifications are probably advantageous: (1) Have the water in the second vessel 143½° F. and immerse the seed five minutes, cooling with cold water afterwards. Where large amounts of seed are to be treated this will prove the most speedy form of the treatment, but great care must be taken to see that every grain is thoroughly wetted. (2) Have the water in the second vessel at 132½° F.; immerse the seed ten minutes and do not cool with cold water, but spread out at once to dry. This last is no doubt the best form of the Jensen treatment for oats, since it requires a shorter time than the regular method and the warmth of the grain aids it materially in drying. Moreover, experiments have shown that seed treated in this way yields the most grain and straw. Neither of these modifications can be recommended for wheat without more data than we now possess.

Potassium sulphide treatment for oats.—In this treatment the seed is left twenty-four hours in a one-half per cent solution of potassium sulphide. The published experiments seem to show that a weak solution of potassium sulphide is nearly as good as the hot water. The potassium sulphide is cheapest in the "fused" condition, in which form it costs about 25 cents a pound. One pound of the sulphide should be dissolved in 24 gallons of water. Place the seed in a *wooden vessel* and pour on the solution till the seed is covered several inches deep. Stir the solution before pouring it on the grain and thoroughly mix the seed several times before taking it out of the solution. The oats should stand in the solution twenty-four hours, after which they may be spread out to dry. The solution gradually loses its strength and hence can not be used more than three or four times without being renewed.

It will probably be best to sow the seed as soon as possible and before it becomes thoroughly dry.

Soaking the seed twelve hours in a solution of twice the strength will no doubt prove effectual.

Copper sulphate treatment for wheat.—This consists in immersing the seed in a solution made by dissolving 1 pound of commercial copper sulphate in 24 gallons of water for twelve hours and then putting the seed for five or ten minutes into lime water made by slaking 1 pound of good lime in 10 gallons of water.

These treatments have all been tried and have proved effective. Probably the hot water is the best for general use. In some parts of the country seed wheat is treated in strong solutions of copper sulphate and no lime is used. This practice is much inferior, since it injures the seed, while those given here prevent the smut completely and at the same time do not injure the seed if carefully followed. In all forms of seed treatment care should be taken to spread the grain out to dry at once and by frequent stirring prevent its spoiling. The treated seed should be handled only with clean tools and should be put in sacks disinfected by boiling fifteen minutes. If these precautions are not taken the seed may be infected again after treatment, especially in case of stinking smut of wheat. If the seed is to be sown broadcast it will not have to be so dry as if it is to be drilled. The seed may be treated with hot water a considerable time before planting if dried carefully, but it is probably better to treat just before planting.

In conclusion, this bulletin will fail of its object if it does not induce *you* to treat your oats and wheat this year. It should be remembered that the recommendations here given are not from theoretical grounds alone, but are justified by the results of extended and laborious experiments many times repeated.

PUBLICATIONS ON THE SUBJECT.

The following list, comprising the more important of the recent publications in English, is given for the benefit of any who may desire to look up the matter further:

Jensen, J. L. Propagation and Prevention of Smut in Oats and Barley, in Journal of the Royal Agricultural Society of England. Vol. 24, second series, Part 2, 1888; also reprinted pages 1–19.

Kellerman, W. A., and Swingle, W. T. Report on the Loose Smuts of Cereals. In Second Annual Report of Experiment Station, Kansas State Agricultural College (at Manhattan, Kans.) for 1889, pages 213–288, plates 1–19.

Arthur, J. C. Treatment of Smut in Wheat. Bulletin 32, vol. 2, Purdue University Agricultural Experiment Station, La Fayette, Ind. July, 1890.

Kellerman, W. A., and Swingle, W. T. Preliminary Experiments with Fungicides for Stinking Smut of Wheat. Bulletin 12, Experiment Station, Kansas State Agricultural College. August, 1890.

Kellerman, W. A., and Swingle, W. T. Additional Experiments and Observations on Oat Smut made in 1890. Bulletin 15, Experiment Station, Kansas State Agricultural College. December, 1890.

Bolley, L. H. Grain Smuts. Bulletin No. 1, Government Agricultural Experiment Station for North Dakota (at Fargo). 1891.

Arthur, J. C. Loose Smut of Oats. Bulletin 35, vol. 2, Purdue University Agricultural Experiment Station. March, 1891.

Kellerman, W. A. Second Report on Fungicides for Stinking Smut of Wheat. Bulletin 21, Experiment Station, Kansas State Agricultural College. August, 1891.

Kellerman, W. A. (1) Smut of Oats in 1891. (2) Tests of Fungicides to prevent Loose Smut of Wheat. Bulletin 22, Experiment Station, Kansas State Agricultural College. August, 1891.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 6.

TOBACCO:

INSTRUCTIONS FOR ITS CULTIVATION AND CURING.

BY

JOHN M. ESTES,
SPECIAL AGENT.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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Farmers' Bulletin No. 5. Treatment of Smuts of Oats and Wheat. (Describes the smuts of wheat, oats, and barley, the damage they cause, and the various methods of treatment which have been found useful for their prevention.) Prepared by the Division of Vegetable Pathology; pp. 8. Issued February, 1892.

TOBACCO: INSTRUCTIONS FOR ITS CULTIVATION AND CURING.

CULTIVATION OF THE TOBACCO PLANT.

The plant is first raised in seed beds till large enough to transplant, the same as cabbage and tomato plants. These beds should be properly located and carefully prepared.

SEED BED ON NEW LAND.

Select a sheltered spot sloping gently to the south and well exposed to the rays of the sun. Upon this plat burn brush or wood until the soil is made hot enough to kill the seeds of grass and weeds. With a hoe or spade stir the earth 2 or 3 inches deep, but do not disturb the subsoil. If, in preparing a seed bed on new land, an inch of the surface soil is removed or the subsoil is brought to the surface, plants will not grow. Rake and work the bed until the surface has been made mellow and fine; well-rotted manure spread over the surface and thoroughly raked in will promote the growth of the plants. Remove all roots and trash; run shallow trenches or hard-beaten paths at intervals of 4 or 5 feet through the bed, and dig a trench 4 or 5 inches deep on the upper side and at the ends; without this protection heavy rains will drift the seed and cover many of them too deeply.

One tablespoonful of seed will sow a bed 10 feet square, which will furnish plants enough to set an acre. Mix the seed with dry ashes and sow evenly. Brush or rake in the seed very lightly. Compact the earth by treading with the feet or by the use of a light roller, leaving the surface smooth and even. Cover with light brush thick enough to slightly shade the plants and protect them from frost or drying winds. The brush may be left upon the bed until the plants are half grown to the size for transplanting. Leaves or trash which accumulate upon the bed must be removed. Something heavier, like pine or cedar boughs or cornstalks, may be used as a covering for the bed, but these must be removed soon after the plants are up.

SEED BEDS ON OLD LAND.

The practice is to burn the surface until the soil is baked half an inch deep. This is done to effectually destroy foul seeds and because the plants grow best, as many believe, upon soil that has been thus baked.

As soon as the bed has cooled off the soil is stirred and worked to a depth of 3 inches, being reversed as little as possible. A liberal application of well-rotted manure or commercial fertilizer is made, and the bed is worked until it is put in fine condition.

If the seed is sprouted before being sown, and the beds are covered with canvas, plants large enough to transplant may be obtained in from thirty to forty days.

HOW TO SPROUT THE SEED.

Upon several layers of woolen cloth spread the seed about one-quarter of an inch thick. Cover well with woolen cloth, thoroughly soak the whole mass with warm water, and set in a warm place near the stove. Keep moist with warm water. In three or four days small white spots will indicate germination. Thoroughly mix the seed with dry ashes and sow.

HOW TO COVER WITH CANVAS.

The bed should be 5 feet 6 inches wide, with a southern exposure. Place boards 6 inches wide around the bed, and to keep these on edge fasten by driving small stakes on each side, or drive stakes and nail the boards to them. Across this frame, at intervals of 3 feet, fasten narrow strips to support the cloth. Bank up with earth. Two widths of light cotton cloth sewed together will form the cover. Upon the sides and ends of this cover sew small loops of cloth or heavy twine. Stretch the cover over the frame and fasten the loops to nails driven at proper distances in the outside of the frame. The cotton cloth used for covering the beds should be a medium between the common grade and what is known as cheese cloth. The cover should be removed a few days before the plants are set out.

HOW TO HASTEN THE GROWTH OF PLANTS.

Set up a leach of well-rotted manure. Manure from the chicken house is the best. To one part of the liquid from the leach add three parts of water and sprinkle upon the plants. Strong liquid manure will injure or kill the plants, but if used at proper strength it is the best fertilizer that can be applied.

Beginners are apt to make a mistake at the very outset in not raising plants enough.

PREPARATION OF THE SOIL FOR TRANSPLANTING.

Old land should be plowed to a depth of 8 inches early in the fall. In February apply stable manure or commercial fertilizer, or both, and plow under to a depth of 3 or 4 inches. The last of April or the first of May, or earlier, as the season permits in the Southern States, plow the land again to the same depth that it was plowed in

February, and with drag or harrow and roller pulverize it thoroughly. Sod land plowed late in the fall, or in the winter or spring, should not be replowed with the turn plow, but should be put in good condition with the double-shovel plow, cultivator, and drag.

With a marker made for the purpose, lay off the land in rows 3 feet 3 inches apart each way, and with a hoe make small hills at the intersection of the rows. Instead of hills, "lists" or ridges may be made by throwing two or four furrows together with a light-turn plough drawn by one horse. The "list" or ridge thus made should be trimmed and patted with the hoe at the proper place for hills.

In preparing land for a crop of tobacco the soil should be put in such perfect condition that no future cultivation should be required, except to kill the weeds and keep the surface mellow.

TRANSPLANTING TOBACCO.

About the 1st of May, or as soon as warm growing weather, according to climate and season, is assured, the plants should be set out. Showery or damp cloudy weather affords the best time for doing this. When the largest leaves are 2½ inches wide the plant is large enough to set.

Saturate the plant beds by pouring water carefully upon them. This will loosen the soil so that the plants may be drawn with the least possible injury to the roots. Pull the plants carefully, one at a time, laying them straight and in a position to protect the leaves from mud and dirt. In setting out tobacco a hole is made in the hill with the fingers or a short sharpened stick. Into this opening the roots of the plant are inserted and the earth is pressed firmly about them. In transplanting tobacco it is important to obtain an even stand. When the plants grow evenly they may be cultivated easily and effectively, and they may all be topped and harvested at the same time. To obtain this even stand or growth, the soil must be put in good condition, the hills must be made of mellow earth and well firmed or patted with the hoe, the deadly cutworm must be hunted out and killed, and good plants must be set in place of those destroyed at the first opportunity.

CULTIVATION.

The best time to kill the weeds is just before they appear upon the surface. Stir the soil often and keep it loose and mellow. If the soil is heavy or has been beaten down with rain, the first cultivation should be deep. The roots of the tobacco plant grow rapidly, soon filling the earth completely between the rows. The tobacco field should, therefore, be well cultivated early in the season, and late cultivation, if necessary, should be shallow.

The hornworm generally puts in an early appearance, and it must be hunted diligently throughout the season and destroyed, or it will greatly injure or ruin the crop. The first week of its existence is occupied in eating several small holes in the leaf near the spot where the egg was deposited by the parent moth, generally upon a lower leaf. These small holes indicate its hiding place during the first week of its life and will aid in its discovery.

PRUNING AND TOPPING.

Pruning consists in stripping off the lower leaves, leaving the stalk bare 6 or 8 inches above the surface of the hill. In topping, that is, removing the upper or flower stalk, from 8 to 12 leaves are left upon the plant, according to strength of soil, type of tobacco, etc. Good soil will mature a greater number of leaves than poor soil, and the bright varieties are topped higher than the dark or export varieties.

The leaves of the tobacco plant stand in eight perpendicular ranks. The ninth leaf stands over the first. This fact will assist the beginner in determining the number of leaves upon a plant without counting them. With practice the point at which a plant should be topped can be fixed at a glance.

Suckers should not be allowed to sap the plant. They should be broken off every week, care being taken not to injure the leaves.

CUTTING AND CURING.

About six weeks after the plant has been topped it will have fully attained its growth. The leaves will become thick and brittle, breaking easily, and they change in color from green to a pale yellowish green. These conditions indicate that the plant is ripe and ready for the harvest. With a thin butcher knife the stalk is split from the top to within a few inches of the bottom leaves; the stalk is then cut just below the lowest leaves. The plant is placed astride upon sticks, and these sticks are hung out of doors upon a scaffold, which consists of two poles standing on an incline as far apart as the sticks are long, so that the plants hanging from the sticks will not interfere; or else the plants are conveyed immediately to the curing barn.

SUN-CURED TOBACCO.

Sun-cured tobacco is hung first upon scaffolds for from five to ten days, according to the weather, and is then hung in the barn, where it is cured by air alone, no fire being used.

Properly constructed barns for curing tobacco by this process, or by what is known as the air-curing process, should be built practically air-tight, with adjustable ventilators. Rail pens or cheap and open sheds are, however, often used as a makeshift from lack of means or desire to erect better buildings.

CURING WITH OPEN FIRES.

The custom of curing tobacco with open fires is still practiced to some extent. The tobacco is placed upon scaffolds four or five days until it is well yellowed, when it is hung in the barn and fires are kindled under it. The fires are made to burn with the least possible blaze, slowly at first, but the heat is gradually increased, and maintained continuously until the leaf, except the upper half of the stem, is entirely cured. This process is fast losing its old-time popularity, and will doubtless soon be superseded by better methods.

CURING BRIGHT TOBACCO WITH FLUES.

This is a somewhat difficult process, requiring practice to insure the best results. The curing-barn should be made nearly air-tight and provided with ample ventilation readily controlled. We give the Ragland method:

First. Yellowing process, 90 degrees, from twenty-four to thirty hours.

Second. Fixing color, 100 degrees, four hours; 100 to 110 degrees, increasing 2½ degrees every two hours; 110 to 120 degrees, four to eight hours.

Third. Curing the leaf, 120 to 125 degrees, six to eight hours.

Fourth. Curing stalk and stem, 125 to 170 degrees, increasing 5 degrees an hour, and continue at 170 degrees until stalk and stem are thoroughly killed and dry, which usually requires from twelve to fifteen hours.

After the tobacco has been cured it must be stripped and sorted, *during damp weather*, and, if not sold loose, it must be bulked or rehung and packed. It should be handled only when in good order. The leaves are generally sorted as they are stripped from the stalk into five or six grades—three or four of leaf and two of lugs. The different grades are tied in small bands or bundles, and the crop is sold loose or placed on the sticks and hung up as soon as stripped, to be taken down and packed in spring or summer.

EFFECTS OF CLIMATE.

Success in the production of tobacco involves not only a knowledge of the best methods to be employed in its culture and curing, but also a knowledge of what types can be most successfully raised in different localities and upon different soils. And when it is known what class of tobacco may be produced in any locality, it is also necessary to know what varieties must be cultivated to produce the most perfect type of that class.

Climate determines the class of tobacco which may be produced within certain areas. Thus the fortieth parallel marks, quite abruptly, the boundary line between the cigar-leaf districts on the north and the regions which produce the manufacturing and export types south of that line.

Between the fortieth and thirty-fifth parallels of latitude lies the great tobacco belt of the United States, where tobacco has always been a leading crop and where its cultivation is generally well understood. South of the thirty-fifth parallel, in the States of South Carolina, Georgia, Alabama, and Mississippi, tobacco has been grown to some extent, mainly for home consumption, in nearly every county since the date of the earliest settlements. Its cultivation in these States has never been followed as a regular industry. What varieties and types will succeed here best is not, therefore, definitely known. These facts can be ascertained only by careful experiment. We know, however, that for several years past South Carolina has produced an excellent type of bright tobacco, and that Florida has produced the highest grade of cigar leaf.

These facts indicate that bright tobacco may be successfully grown in the northern portions of Georgia and Alabama, and that cigar tobacco, of the Cuban type, may be profitably cultivated in the extreme southern portions of those States; while if we judge of the types of tobacco which may be raised in Mississippi from those which are produced in contiguous States, both the bright and the dark heavy varieties may be grown there, varying according to soil.

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 7.

SPRAYING FRUITS

FOR

INSECT PESTS AND FUNGOUS DISEASES,

WITH

A SPECIAL CONSIDERATION OF THE SUBJECT IN ITS RELATION TO THE PUBLIC HEALTH.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1892.

FARMERS' BULLETINS.

The bulletins of this series may be obtained by applying to the Secretary of Agriculture, Washington, D. C. The following have been previously issued:

Farmers' Bulletin No. 1. The What and Why of Agricultural Experiment Stations. (A brief explanation of the object, origin, and development of the stations, their work in Europe and in the United States, and the operations of the Office of Experiment Stations of the Department of Agriculture.) Prepared by the Office of Experiment Stations; pp. 16. Issued June, 1889.

Farmers' Bulletin No. 2. The work of the Agricultural Experiment Stations; (Illustrations of Station Work in the following lines: better cows for the dairy; fibrin in milk; bacteria in milk, cream, and butter; silos and silage; alfalfa; and field experiments with fertilizers.) Prepared by the Office of Experiment Stations; pp. 16. Issued June, 1889.

Farmers' Bulletin No. 3. The Culture of the Sugar Beet. (Treats of the climatic conditions, soil, fertilizers, and cultivation required by the sugar beet, cost of growing, time to harvest, and method of soiling; describes briefly the process of beet-sugar manufacture, and gives statistics of sugar production and consumption.) By H. W. Wiley, chemist of the Department of Agriculture; pp. 24. Issued March, 1891.

Farmers' Bulletin No. 4. Fungous Diseases of the Grape and their Treatment. (Describes downy mildew, powdery mildew, black rot, and anthracnose of grapes, and gives instructions for their treatment and estimated cost of remedies.) By B. T. Galloway, Chief of the Division of Vegetable Pathology; pp. 12. Issued March, 1891.

Farmers' Bulletin No. 5. Treatment of Smuts of Oats and Wheat. (Describes the smuts of wheat, oats, and barley, the damage they cause, and the various methods of treatment which have been found useful for their prevention.) Prepared by the Division of Vegetable Pathology; pp. 8. Issued February, 1892.

Farmers' Bulletin No. 6. Tobacco: Instructions for its cultivation and curing. Prepared by John M. Estes, special agent; pp. 8. Issued February, 1892.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF THE ASSISTANT SECRETARY,
Washington, D. C., March 10, 1892.

SIR: I have the honor to transmit herewith for publication a bulletin prepared in accordance with my direction by the Divisions of Entomology and Vegetable Pathology, to be included in the series of farmers' bulletins of this Department, treating of the practice, methods, and effects of spraying fruit trees for insect pests and fungous diseases. This practice has been widely extended during the past few years, largely upon the lines laid down by this Department as the result of careful and extended experiments. The fact that the compounds as generally used are slightly poisonous in their character has led some persons to express apprehension lest their application should injure the fruit for consumption. This apprehension has been shown over and over again to be ill founded, frequent experiments under all possible conditions having shown that no spraying as prescribed by the Department experts has ever resulted in the slightest deleterious effects upon the fruit subjected to it. While this bulletin presents the subject of spraying in the most practical manner for the information of the orchardist and fruit-grower, it is mainly intended for the information and satisfaction of the consumer, by showing him exactly the character of the spraying recommended, and the utter impossibility of evil consequences to him.

The publication of this bulletin in this brief and practical form is rendered especially necessary and timely by the fact that persons antagonizing, from interested motives, the importation of American fruit into Great Britain have indulged in the frequent assertion that spraying as practiced in this country must necessarily have deleterious effects upon the fruit and injure it for consumption. It is believed that the present bulletin, and the simple facts therein arrayed, will serve a useful purpose in thoroughly exploding the baseless charges which have been leveled on this score against American fruits in Great Britain and other countries.

Respectfully,

EDWIN WILLITS,
Assistant Secretary.

HON. J. M. RUSK,
Secretary.

SPRAYING FOR INSECT PESTS AND FUNGOUS DISEASES.

SPRAYING FOR INSECT PESTS.

The distribution of insecticide mixtures in the form of spray was first begun in this country on a large scale during the early spread of the Colorado potato-beetle in the Western States. Paris green was first used in 1869 both as a dry mixture diluted with flour, ashes, plaster, or slacked lime, and in liquid suspension in water. Spray machines soon came into use, and this method of application of insect-destroying mixtures was speedily extended to other insect pests. In 1878 poisoned spray was first used against the codling-moth, and the Entomologist of the Department had previously recommended this remedy for the cotton-worm and several other leaf-eating insects. During the progress of the investigation of the cotton-worm many spraying machines were developed, and from that time to the present the development of methods and machinery has been rapid, until at the present time the best remedies against perhaps the majority of our principal insect pests comprehend the application of an insecticide spray at one time or another.

INSECTICIDES USED IN THE FORM OF A SPRAY.

Kerosene emulsion.—This insecticide acts by contact and is applicable to all nonmasticating insects (sucking insects, such as the true bugs and especially plant-lice and scale-insects) and also to many of the mandibulate or masticating insects, such as the apple worm or plum curculio, when the use of arsenites is not advisable. Kerosene emulsion may be made by means of various emulsifying agents, but the most satisfactory substances—and those most available to the average farmer and fruit-grower—are milk and soapsuds. In each of these cases the amount of emulsifying agent should be one-half the quantity of kerosene.

One of the most satisfactory formulas is as follows:

			Per cent.
Kerosene	gallons	2	67
Common soap or whale-oil soap	pounds	½	33
Water	gallons	1	

Heat the solution of soap and add it boiling hot to the kerosene. Churn the mixture by means of a force pump and spray nozzle for five or ten minutes. The emulsion, if perfect, forms a cream which thickens upon cooling and should adhere without oiliness to the surface of glass. If the water from the soil is hard or has a large percentage of lime, add a little lye or bicarbonate of soda, or else use rain-water. For use against scale-insects, dilute one part of the emulsion with nine parts of cold water. For most other insects, dilute one part of the emulsion with fifteen parts of water. For soft insects, like plant-lice, the dilution may be carried to from 20 to 25 parts of water.

The milk emulsion is produced by the same methods as the above.

The resin washes.—These insecticides act by contact, and also, in the case of scale-insects, by forming an impervious coating which effectually smothers the insects treated. These resin washes vary in efficacy according to the insect treated. Experience has shown that the best formula for the red scale (*Aspidiotus aurantii* Maskell) and its yellow variety (*A. citrinus* Coquillett) is as follows:

Resin	pounds	18
Caustic soda (70 per cent strength)	do	5
Fish oil	pints	2½
Water to make	gallons	100

The necessary ingredients are placed in a kettle and a sufficient quantity of cold water added to cover them. They are then boiled until dissolved, being occasionally stirred in the meantime, and after the materials are dissolved the boiling should be continued for about an hour, and a considerable degree of heat should be employed so as to keep the preparation in a brisk state of ebullition, cold water being added in small quantities whenever there are indications of the preparation boiling over. Too much cold water, however, should not be added at one time, or the boiling process will be arrested and thereby delayed, but by a little practice the operator will learn how much water to add so as to keep the preparation boiling actively. Stirring the preparation is quite unnecessary during this stage of the work. When boiled sufficiently it will assimilate perfectly with water, and should then be diluted with the proper quantity of cold water, adding it slowly at first and stirring occasionally during the process. The undiluted preparation is pale yellowish in color, but by the addition of water it becomes a very dark brown. Before being sprayed on the trees it should be strained through a fine wire sieve, or through a piece of Swiss muslin, and this is usually accomplished, when pouring the liquid into the spraying tank, by means of a strainer placed over the opening through which the preparation is introduced into the tank.

The preparing of this compound will be greatly accelerated if the resin and caustic soda are first pulverized before being placed in the boiler, but this is quite a difficult task to perform. Both of these substances are put up in large cakes for the wholesale trade, the resin being in wooden barrels, each barrel containing a single cake, weighing about 375 pounds, while the caustic soda is put up in iron drums containing a single cake each, weighing about 800 pounds. The soda is the most difficult to dissolve, but this could doubtless be obviated by first dissolving it in cold water and then using the solution as required. This insecticide may be applied at any time during the growing season.

A stronger wash is required for the San José scale (*Aspidiotus perniciosus* Comstock), and the following formula gives the best results:

Resin	pounds	30
Caustic soda (70 per cent)	do	9
Fish oil	pints	4½
Water enough to make	gallons	100

Place all the ingredients in a kettle and cover with water to a depth of 4 or 5 inches; boil briskly for about two hours, or until the compound can be perfectly dissolved with water. When this stage is reached the kettle should be filled up with water, care being taken not to chill the wash by adding large quantities of cold water at once. It may be thus diluted to about 40 gallons, the additional water being added from time to time as it is used.

This preparation should only be applied during winter or during the dormant period; applied in the growing season it will cause the loss of foliage and fruit.

In the application of both these washes a very fine spray is not essential, as the object is not simply to wet the tree, but to thoroughly coat it over with the compound, and this can be best accomplished by the use of a rather coarse spray, which can be thrown upon the tree with considerable force.

THE ARSENITES: LONDON PURPLE, PARIS GREEN, AND WHITE ARSENIC.

These poisons are of the greatest service against all masticating insects, as larvæ and beetles, and they furnish the most satisfactory means of controlling most leaf-feeders, and the best wholesale remedy against the codling-moth. Caution must be used in applying them, on account of the liability of burning or scalding the foliage.

The poisons should be thoroughly mixed with water at the rate of from 1 pound to 100 to 250 gallons of water, and applied with a force pump and spray nozzle. In preparing the wash, it will be best to first mix the poison with a small quantity of water, making a thick batter, and then dilute the latter and add to the reservoir or spray tank, mixing the whole thoroughly. When freshly mixed, either London purple or Paris green may be applied to apple, plum, and other fruit trees, except the peach, at the rate of 1 pound to 150 to 200 gallons, the latter amount being recommended for the plum, which is somewhat more susceptible to scalding than the apple. White arsenic does little, if any, injury at the rate of 1 pound to 50 gallons of water when freshly mixed. As shown by Mr. Gillette, however, when allowed to remain for some time (two weeks or more) in water, the white arsenic acts with wonderful energy, scalding when used at the rate of 1 pound to 100 gallons from 10 to 90 per cent of the foliage; the action of the other arsenites remains practically the same, with perhaps a slight increase in the case of London purple.

With the peach these poisons, when applied alone, even at the rate of 1 pound to 300 or more gallons of water, are injurious in their action, causing the loss of much of the foliage.

By the addition of a little lime to the mixture, London purple and Paris green may be safely applied, at the rate of 1 pound to 125 to 150 gallons of water, to the peach or the tenderest foliage, or in much greater strength to strong foliage, such as that of the apple or most shade trees.

Whenever, therefore, the application is made to tender foliage or when the treating with a strong mixture is desirable, limewater, milky, but not heavy enough to close the nozzle, should be added at the rate of about 2 gallons to 100 gallons of the poison.

With the apple, in spraying for the codling-moth, at least two applications should be made, the first after the falling of the blossoms or when the apples are about the size of peas, and the second a week or ten days later. The first brood of the codling-moth lays its eggs in the flower end of the young apple, and the worms upon hatching gnaw their way into the interior of the apple, and on sprayed trees get poisoned in so doing, an infinitesimal amount being sufficient to destroy so minute a worm. The second spraying is for the purpose of destroying larvæ hatching from eggs which may be laid after the first spraying, as the arsenic is gradually washed off by rains.

For the plum curculio on the plum, cherry, peach, etc., two or three applications should be made during the latter part of May and the first half of June. The poison in this case is applied for the purpose of destroying the adult curculios which hibernate and gnaw into the young growth of the trees and even into the hard young fruit before laying their eggs. The eggs are pushed under the skin so that the larvæ are not ordinarily affected by the poisoning.

In the case of most leaf-feeding insects one should spray on the first indication of their presence.

Caution necessary in the use of these insecticides.—The relative susceptibility of apple, plum, and peach has just been indicated under the head of arsenical poisons, and these remarks apply equally well to the use of the kerosene emulsions. In the case of other plants thorough experiments are still necessary, and all insecticides should be used in comparatively high dilution. Tender-leaved plants, such as melons and cucumbers, are more readily injured; while plants with firmer and smooth leaves, like the orange, are least affected. Annual plants, such as cabbages and other garden vegetables, are more susceptible than perennials; but in the case of root crops, such as beets, turnips, radishes, and potatoes, there is not the same need of caution as to damage to foliage. Damage to foliage is not shown at once, and in case of rain following an application another application should not be made for several days. Fruit trees should not be sprayed with arsenical poisons while in blossom, as there is no advantage in doing so, and honeybees are reported to be at times killed by working in the sprayed blossoms.

SPRAYING FROM THE HYGIENIC STANDPOINT.

The only insecticide sprays which are at all dangerous to use are the arsenic compounds, and even here the danger is greatly exaggerated by those not conversant with the facts. Paris green and London purple have for many years been extensively used in this country as insecticides and a case of fatal poisoning from their use as such has never been substantiated. The only danger lies in having the poison about a farm or plantation in bulk. In the early days of the use of Paris green against the Colorado potato-beetle a great deal of opposition was developed on account of the supposed danger, and only recently the sale of American apples in England has received a set-back owing to the supposed danger of arsenic poisoning from their consumption. The question as to whether arsenic may be absorbed by the growing plant in any degree was long ago settled in the negative by the best chemists in the country. Dr. William McMurtrie, formerly chemist of this Department, in 1878 showed that even where Paris green was applied to the soil in such quantities as to cause the wilting or death of the plants, the most rigorous chemical analysis could detect no arsenic in the composition of the plants themselves. Other experiments in a similar direction by Prof. R. C. Kedzie, of the Michigan Agricultural College, confirmed these conclusions. It is safe, then, to assume that the only way in which fruit or vegetables can convey the poison to the consumer will be through the very minute quantity of arsenic left upon the edible part of the plant. Against the possibility of such an effect the following facts may be urged:

(1) It would seem at first glance that the use of an arsenical poison upon a plant like the cabbage would be very unsafe to recommend, yet Paris green and London purple are used upon this crop to kill the several species of leaf-eating worms which are so destructive to it, and an absolute absence of all danger where the application has been properly made has been recently shown by Prof. Gillette, of the Agricultural Experiment Station of Colorado, by the following *reductio ad absurdum:*

> * * * Where the green is dusted from a bag in the proportion of 1 ounce of the poison to 100 ounces of flour and just enough applied to each head to make a slight show of dust on the leaves, say, for twenty-eight heads of cabbage, 1 ounce of mixture, the worms will all be killed in the course of two or three days, while the average amount of poison on each head will be about one-seventh of a grain. Fully one-half of the powder will fall on the outside leaves and on the ground, and thus an individual will have to eat about twenty-eight heads of cabbage in order to consume a poisonous dose of arsenic, even if the balance of the poison remained after cooking.

(2) In case of spraying apple orchards for the codling-moth there is scarcely a possibility of injury to the consumer of the fruit. A mathematical computation will quickly show that where the poison is used in the proportion of 1 pound to 200 gallons of water (the customary proportion) the arsenic will be so distributed through the water that it will be impossible for a sufficient quantity to collect upon any given apple to have the slightest injurious effect upon the consumer. In fact, such a computation will indicate beyond all peradventure that it will be necessary for an individual to consume several barrels of apples at a single meal in order to absorb a fatal dose even should this enormous meal be eaten soon after the spraying and should the consumer eat the entire fruit.

(3) As a matter of fact careful microscopic examinations have been made of the fruit and foliage of sprayed trees at various intervals after spraying which indicate that after the water has evaporated the poison soon entirely disappears either through being blown off by the wind or washed off by rains, so that after fifteen days hardly the minutest trace can be discovered.

(4) In the line of actual experiment as indicating the very finely divided state of the poison and the extremely small quantity which is used to each tree Prof. A. J. Cook, of the Michigan Agricultural College, has conducted some striking experiments. A thick paper was placed under an apple tree which was thoroughly sprayed on a windy day so that the dripping was rather excessive. After the dripping had ceased, the paper (covering a space of 72 square feet) was analyzed and four-tenths of a grain of arsenic was found. Another tree was thoroughly sprayed and subsequently the grass and clover beneath it was carefully cut and fed to a horse without the slightest sign of injury.

The whole matter was well summed up by Professor Riley in a recent lecture before the Lowell Institute, in Boston, in the following words:

> The latest sensational report of this kind was the rumor, emanating from London, within the last week, that American apples were being rejected for fear that their use was unsafe. If we consider for a moment how minute is the quantity of arsenic that can, under the most favorable circumstances, remain in the calyx of an apple, we shall see at once how absurd this fear is; for, even if the poison that originally killed the worm remained intact, one would have to eat many barrels of apples at a meal to get a sufficient quantity to poison a human being. Moreover, much of the poison is washed off by rain, and some of it is thrown off by natural growth of the apple, so that there is, as a rule, nothing left of the poison in the garnered fruit. Add to this the further fact that few people eat apples raw without casting away the calyx and stem ends, the only parts where any poison could, under the most favorable circumstances, remain, and that these parts are always cut away in cooking, and we see how utterly groundless are any fears of injury and how useless any prohibitive measures against American apples on this score.

SPRAYING FOR FUNGOUS DISEASES OF THE APPLE, PEAR, AND OTHER FRUITS.

Probably in no other country of the world is spraying for fungous diseases of fruits practiced to the same extent as in the United States. Five years ago practically nothing was known of this subject; in fact, the number actively engaged in spraying their trees, vines, etc., for such diseases as apple scab, black-rot, downy mildew, and other diseases of the grape did not exceed half a hundred all told. Now, as a fair estimate, probably no less than 50,000 fruit-growers are engaged in this work. From the Atlantic to the Pacific and from the Great Lakes to the Gulf the methods recommended by the Department are practiced every year. Canada has also adopted many of the suggestions made by us, and even now Australia is actively engaged in experiments in the treatment of apple, pear, peach, and other diseases, in accordance with suggestions originating with this Department.

DOES IT PAY TO SPRAY?

This question is in large part answered by the facts already given. No work that did not carry merit with it could have had such a phenomenal growth. To give a more direct answer, however, it may be stated that last season two hundred and fifty grape-growers in different parts of the country made a series of observations with a view of obtaining some definite information as to the value in dollars and cents of the recommendations made by the Department in the treatment of grape diseases. The facts reported by these men show conclusively that the actual profit to them over all expenses resulting from the treatment of black-rot and downy mildew was in round numbers $37,000. Thirteen thousand dollars of this sum was reported from the State of New York alone.

Other examples equally as striking could be given, but this is sufficient for our purpose. Of course, every one is not successful, but where failure is reported it is usually easy to locate and remedy the trouble.

FUNGICIDES OR REMEDIES USED IN SPRAYING.

Numerous preparations have been recommended and used for this work. For all practical purposes, however, there are but four which properly may be called remedies. They are (1) Bordeaux mixture, (2) ammonaical solution of copper carbonate, (3) eau céleste, and (4) modified eau céleste. The latest experiments indicate that the best results will follow the use of these preparations when made as follows:

1.—BORDEAUX MIXTURE.

In a barrel that will hold 45 gallons dissolve 6 pounds of copper sulphate, using 8 or 10 gallons of water or as much as may be necessary for the purpose. In a tub or half barrel slake 4 pounds of *fresh* lime. When completely slaked add enough water to make a creamy whitewash. Pour this slowly into the barrel containing the copper-sulphate solution, using a coarse gunny sack stretched over the head of the barrel for a strainer. Finally fill the barrel with water, stir thoroughly, and the mixture is ready for use. Prepared in this way the cost of 1 gallon of the mixture will not exceed 1 cent, the price of copper sulphate being 7 cents per pound and lime 30 cents per bushel. In all cases it is desirable to use powdered copper sulphate, as it costs but little more and dissolves much more readily. It is highly important also that fresh lime be used.

It will be seen by those familiar with former suggestions made by the Department that the strength of this mixture has been diminished one-half. It was found as the result of experiments made in 1891 that a mixture of this strength, and even much weaker, gave practically as good results as the old formula, which required 6 pounds of copper sulphate and 4 pounds of lime to 22 gallons of water.

2.—AMMONIACAL SOLUTION OF COPPER CARBONATE.

In an ordinary water pail mix 5 ounces of copper carbonate with enough water to make a thick paste. Dissolve this paste in 3 pints of strong aqua ammonia; then dilute to 45 gallons. If three pints of ammonia are not sufficient to dissolve all the paste add enough to bring about this result. Copper carbonate occurs in the market in the form of a fine greenish powder. The retail price is usually 60 cents per pound. Aqua ammonia having a strength of 26° retails at 8 cents per pound. Upon this basis 1 gallon of the ammoniacal solution of copper carbonate will cost 1 cent.

In view of the fact that copper carbonate is sometimes difficult to obtain the following directions for manufacturing it are given:

In a half barrel, or some similar vessel, dissolve 3 pounds of copper sulphate in 2 gallons of hot water. In another vessel dissolve 3½ pounds of common washing soda or sal soda in 1 gallon of hot water. When cool pour the second solution slowly into the first; then as soon as all action has ceased add enough water to bring the whole up to 8 or 10 gallons and stir thoroughly. In twenty-four hours pour off the clear liquid, taking care not to disturb the sediment. Add fresh water and stir again. Again allow the solution to stand twenty-four hours, pour off the clear liquid as before; then remove the sediment, which is copper carbonate. Prepared in this way there is formed 1½ pounds of copper carbonate at an expense for materials of approximately 18 cents per pound. The copper-carbonate paste may be immediately dissolved in aqua ammonia, using 2 gallons of the latter, or as much as may be necessary for the purpose. This concentrated fluid should be kept in well-corked jugs and when ready for use should be diluted at the rate of 1 pint to 12 gallons of water.

3.—EAU CÉLESTE.

Dissolve 2 pounds of copper sulphate in 8 gallons of water. When completely dissolved add 3 pints of strong ammonia and dilute to 45 gallons. Prepared in this way the solution will cost about two-thirds of a cent per gallon.

4.—MODIFIED EAU CÉLESTE.

Dissolve 4 pounds of copper sulphate in 10 or 12 gallons of water and stir in 5 pounds of washing or sal soda; then add 3 pints of strong aqua ammonia, dilute to 45 gallons. The cost will be 1½ cents per gallon.

HOW AND WHEN TO SPRAY.

It should always be borne in mind that no hard and fast rules can be laid down for work of this kind. Frequently the fruit-grower will have to use his own judgment, especially as regards the number of sprayings and the proper time to discontinue them. If this be not done serious results may follow. In the treatment of black-rot of the grape we have known vine-growers to continue the application of Bordeaux mixture through a protracted drought up to the time of ripening of the fruit. As a result, when the time arrived to send the grapes to market they were so badly spotted with the mixture that no one would buy them. Again we have found fruit-growers thoroughly imbued with the idea that the only proper way to spray was to rush through an orchard or vineyard with some new-fangled complicated machine, applying the solutions in daubs at one point and omitting whole trees or blocks of vines at another. Such work is to be regretted, as it may be the cause of much loss to those who have acted carefully and intelligently in the matter. For example, in the case of the grape scare in New York City the past summer grape-growers all over the country were made to suffer, partly through the folly of a few overzealous individuals who upon their own responsibility made more applications than were necessary and partly through the action of a somewhat hasty Board of Health.

Before taking up the subject of treatments proper it may be well to emphasize the importance and necessity of using the right kind of machinery. A sprayer to be effective requires first of all a good strong force pump. Next in importance is a nozzle that will throw a mist-like spray and will not clog when thick fluids are used. There are plenty of machines on the market filling all these requirements. For convenience they may be divided into three classes: (1) horse-power automatic machines, (2) machines drawn by horse power, but operated by hand, and (3) hand machines. All belonging to the first group may be dismissed with the statement that they are unnecessarily expensive and complicated, and will not, even in the most careful hands, do the work as thoroughly and effectively as the machines belonging to the second and third groups. Of the second group, in which the cheapest, most practical, and efficient example is found in a strong, light, double-acting, double-discharge force pump mounted on a barrel, it may be said that, while they can not do the work as rapidly as the machines of the first class they are more effective, much cheaper, and far less wasteful of the liquid used. To the third class belong the knapsack sprayers, which are the only ones necessary to notice in this connection. There is no question that for all moderately low-growing crops the knapsack sprayer fills every requirement. In no other machine is the work so absolutely at all times under control, it being possible to place nearly every drop of liquid exactly where it is wanted. Knapsack pumps are now used in many moderate sized vineyards; also in places where the horse-power apparatus, owing to the nature of the land or the manner of cultivation, can not be utilized.

Many firms throughout the country, as will be seen by reference to the columns of any good agricultural paper, are engaged in the manufacture and sale of the various machines mentioned.

Taking up the question of spraying more specifically we would call attention first to apple diseases and their treatment.

TREATMENT OF APPLE SCAB.

For this disease either modified eau céleste or ammoniacal solution of copper carbonate, preferably the former, may be used. At least four sprayings should be made, the first just as the flowers are opening, the second twelve or fourteen days later, and the third and fourth at similar intervals. In case the season is wet one or two additional treatments will undoubtedly pay. For trees 15 to 18 feet high the cost of four sprayings with either of the fungicides mentioned need not exceed 20 cents per tree. When the work is done on a large scale 16 to 18 cents per tree will cover the cost of four treatments. Two additional treatments will add to the cost from 6 to 8 cents per tree.

APPLE POWDERY MILDEW.

It is only in nurseries that this disease is destructive. Seedlings are especially subject to the mildew, the leaves being attacked as soon as they appear. As a result the trees make very little growth, are bark bound, and consequently unfit for budding. The ammoniacal solution has proved the cheapest and most effective remedy for this disease, and five sprayings seem to be required. The first application should be made just as the leaves start in spring. At least three other sprayings should be made at equal intervals between the time of the first treatment and the time for budding. Ten or twelve days after budding the last spraying should be made, making five in all. For blocks of 50,000 to 100,000 seedlings the total cost of the treatment, as indicated, need not exceed 8 cents per thousand. In smaller blocks the average cost per thousand trees will be somewhat greater, as it requires practically as much time to prepare to spray 25,000 trees as it does 50,000. The knapsack pump is well adapted to this work and is extensively used by nurserymen. Larger machines, designed to be drawn by a horse, have been described by us in Circular No. 10 of the Division of Vegetable Pathology.

TREATMENT OF PEAR SCAB, CRACKING, AND LEAF-BLIGHT.

These diseases, caused by two different species of fungi, are now successfully combated by one line of treatment. In most sections all three diseases are found associated. Bordeaux mixture has given the best results in this work, although ammoniacal solution has proved almost as effective. The only objection to the latter is that it sometimes gives the fruit a rust appearance, which is not at all desirable. The first spraying for these diseases should be made when the trees are in flower. In ten or twelve days a second treatment should be made, followed by a third and fourth at the expiration of two and four weeks, respectively. In the nursery, pear leaf-blight is often exceedingly troublesome. It may be almost entirely prevented by spraying five or six times with the Bordeaux mixture, making the first application when the leaves are about one-third grown and the others at intervals of ten or twelve days throughout the season.

The cost of treating full-grown standard trees with the Bordeaux mixture as indicated will average from 12 to 14 cents per tree. For dwarf trees the cost will range from 8 to 12 cents each. The cost of treating with the ammoniacal solution will be considerably less, probably not exceeding 10 cents for standard and 8 cents for dwarf trees. In the nursery pear seedlings can be treated six times with the Bordeaux mixture for 50 cents per thousand.

TREATMENT OF LEAF-BLIGHT OF THE CHERRY, PLUM, AND QUINCE.

This disease, which seriously damages the trees both in the nursery and orchard, may be readily held in check by the proper use of either Bordeaux mixture or the ammoniacal solution. In the orchard and nursery the directions laid down for the treatment of pear scab, cracking, and leaf-blight are applicable here.

TREATMENT OF BLACK-ROT OF THE GRAPE.

Method A.—After pruning the vineyard and putting the ground in thorough order spray the vines first, as the buds begin to swell, with Bordeaux mixture. When the leaves are one-third grown make a second application of the same fungicide, following with a third when the vines are in full bloom. After this, applications should be continued at intervals of ten or twelve days until the first signs of ripening are noticed. This will usually be three weeks or a month before the grapes are ready to pick. In no case should the treatments be continued up to the time of harvest, as this is entirely unnecessary; moreover, it is sure to render the fruit unsightly. It is important to bear in mind that in case of dry weather the sprayings should cease.

Method B.—Following the direction laid down under method *A*, with the exception that the ammoniacal solution be used instead of Bordeaux mixture.

Method C.—For the first three sprayings use the Bordeaux mixture, then substitute the ammoniacal solution for the rest of the season.

The cost of the treatment as laid down in method *A* need not exceed $2\frac{1}{2}$ cents per vine. Method *B* will cost two cents and method *C* the same.

So far as efficacy is concerned there is little choice. All things considered, however, method *A* will doubtless prove the most satisfactory.

DOWNY MILDEW OF THE GRAPE.

When this disease occurs alone ammoniacal solution or modified eau céleste may be used. The first spraying should be made when the fruit is well formed, the others at intervals of ten or twelve days, as recommended for black-rot. What is known as brown-rot is caused by the fungus of downy mildew. It is seldom that brown-rot occurs in the berries without the leaves being also affected. In regions where this happens the treatment recommended for black-rot should be followed.

In some sections eau céleste has been more effective against these diseases than any of the other fungicides. This is notably the case in northern Ohio and western New York. Eau céleste, however, sometimes injures the foliage, and we do not advise its extended use.

ANTHRACNOSE OF THE GRAPE.

Use Bordeaux mixture the same as recommended for black-rot under method *A*.

USE OF COPPER COMPOUNDS FROM A HYGIENIC STANDPOINT.

Ever since the copper compounds came into general use as fungicides the question as to their effects, hygienically considered, has received more or less attention. With the exception of the New York City Board of Health no positive stand on this question has been taken so far as we are aware. Many vague and misleading statements, however, have from time to time appeared in the horticultural and agricultural papers. Every one familiar with the situation understands why these rumors, for such they can only be considered, are sent out. They are not aimed particularly at the practice of spraying, but are simply efforts on the part of selfish competitors to cripple the legitimate trade of more energetic and wide-awake rivals.

We take the ground that fruit sprayed with the copper compounds in accordance with the directions of the Department is harmless. No better proof of this is to be found than that shown by the experience of this country. For five years the copper compounds have been used by hundreds and thousands of fruit-growers in every part of the United States, yet in all that time not a single authenticated case of poisoning, so far as we are aware, has been brought to light. It is true a few individuals have claimed that they were made sick by eating sprayed fruit, but in all such cases careful investigations have revealed that claims of this kind were absolutely without foundation. However, we do not consider these general statements sufficient to warrant us in taking the stand as regards the harmlessness of the copper compounds when properly used. More direct testimony is readily obtained and some of this we now propose to consider. The question may properly be discussed under two heads, namely:

(1) The present condition of our knowledge as regards the toxicology of copper; and

(2) Are the salts found in sufficient quantity upon the fruit at the time of harvest to prove injurious to health?

No doubt the majority of people, including physicians, would answer the first statement at once by saying that copper is a poison. When we come to look carefully into the matter, however, it is found that the very best authorities differ on the subject. For more than a hundred years the question as to the poisonous nature of copper has been discussed, and yet, after reading all the testimony, it is exceedingly difficult from the evidence adduced to form a definite opinion.

In 1885 the question was discussed before the Belgium Royal Academy of Medicine for seven months, the object being to obtain some authoritative data as to the effect of copper contained in French canned vegetables on the public health. While it was finally decided that the copper compounds in foods were harmful, no direct stand as to the poisonous nature of the substances was taken. Those who antagonized the view that copper was an actual poison cited many eminent authorities to bear out their assertions. In the whole discussion, however, it was remarkable that not a single case of injury to health resulting from the daily absorption of small quantities of copper was given. Many instances were cited, however, where foods containing copper in considerable amounts were daily consumed without any ill effects whatever. It is interesting to note in this connection that notwithstanding the discussion before the Belgium Academy the law of July, 1882, prohibiting the use of copper in the re-greening of fruits was repealed by the French authorities in the Department of the Seine. It appears, therefore, from all the evidence on the subject that the question under consideration is not settled by any means. For this reason alleged cases of poisoning with copper should receive the most careful investigation.

We presume no one will deny that copper in large or even moderate doses is unwholesome. Looking at the question from this standpoint let us consider the second part of our subject, *i. e.*, Are the salts found in sufficient quantity in connection with properly sprayed fruit at the time of harvest to cause injury to health? At this point it may be well to add that all our remarks apply to the Bordeaux mixture, which contains about twenty times as much copper as the ammoniacal solution, the only additional fungicide worthy of consideration on account of its extended use.

According to Gauthier, professor of chemistry of the faculty of medicine, Paris, an adult can absorb daily for a period of several weeks without ill effects from 0.2 to 0.5 * gram of copper sulphate, or blue vitriol. Five-tenths of a gram is usually considered the maximum amount that may be absorbed for any length of time without injury to health, although cases are on record where as high as 2, 3, and even 4 grams have been absorbed for a number of days in succession without any ill effects whatever. Some recent French investigations have shown that a dog can absorb from 15 to 25 grams of copper sulphate without injury. Sheep have been fed 43 grams per day for several days in succession without any noticeable derangement of the system.

At this point we are confronted with a somewhat complex chemical question which makes it difficult to obtain results strictly comparable. The Bordeaux mixture, as elsewhere shown, is made by the addition of lime to a solution of copper sulphate. According to recent investigations, the reaction is an exceedingly complicated one, the details of which are unnecessary here. It has generally been accepted that the mixture as sprayed upon the vines consists for the most part of copper hydrate, which upon drying becomes an insoluble compound. We have, therefore, first of all the question to consider whether the hydrate is as likely to prove injurious to health as the sulphate in solution. No direct investigations upon this point have, so far as we know, been made. It has been shown, however, that doses of copper four to five times greater can be administered in an insoluble than in a soluble state. The question now briefly stated resolves itself into this: May we, without assuming too much, use the facts bearing on the harmfulness or harmlessness of copper sulphate when considering copper hydrate and copper oxide? We believe that this assumption is not only admissible but is erring upon the safe side; in other words, that if an adult can safely absorb 0.5 gram of copper sulphate a day without injury, he may with much less fear of ill effects absorb the same quantity of copper hydrate and copper oxide. In fact, as regards the ill effects of the latter, hygienically considered, there is a great deal of evidence which will be considered later.

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* 1 gram equals 15.438 grains.

Accepting, then, 0.5 gram as the maximum amount of copper in any of the forms discussed that may with safety be daily absorbed, let us see how these figures compare with the quantity of this metal found in connection with properly sprayed fruits as well as some other foods and drinks. Analyses to determine the amount of copper on sprayed grapes have been made in Germany, France, America, and other countries. The result of all these show that grapes sprayed intelligently rarely contain more than 5 milligrams (0.005 gram) of copper per kilogram, the average being from 2½ to 3 milligrams per kilogram. In other words, 1,000,000 pounds of grapes sprayed in the usual way with the Bordeaux mixture would contain from 2½ to 5 pounds of copper. To reduce the figures still further, each 1,000 pounds of fruit would contain 17.5 to 35.0 grains of copper. On this basis an adult may eat from 300 to 500 pounds of sprayed grapes per day without fear of ill effects from the copper. This shows how ridiculously absurd are the statements that fruits properly sprayed with the Bordeaux mixture or any other copper compound are poisonous.

Turning our attention to another phase of the subject, let us consider some other articles of food and drink in no way connected with spraying. In the first place, it has recently been shown that grapes which have never been treated with any fungicide may contain as much as 2 milligrams of copper per kilogram—two parts in a million, or practically the same as the average amount found in connection with sprayed fruit. Finding copper, therefore, in connection with fruit is no indication that such fruit has been sprayed with the copper compounds. Perhaps if this fact is remembered in the future it may prevent hasty conclusions and consequent annoyance.

According to numerous analyses wheat may contain from 4 to 10 milligrams of copper per kilogram, the average being 7.2 milligrams per kilogram. The United States exported to Europe and other foreign countries in 1890, 54,387,767 bushels of wheat, weighing approximately 3,263,266,020 pounds or 1,480,217,466 kilograms. If each kilogram of wheat contained 7.2 milligrams of copper, then there were 10,657 kilograms or 23,495 pounds of this metal sent out of the country in wheat alone. In the face of these figures we do not see how any foreign country can logically object to American fruits on the ground that they contain copper without also objecting to wheat.

Wheat, however, does not contain anything like as much copper as some other foods and drinks. Beef and sheep liver, according to reliable and repeated analyses, contain respectively from 56 to 58 and 35 to 41 milligrams of metallic copper per kilogram of fresh substance, while in chocolate the enormous amount of 125 milligrams to the kilogram has been found. In conclusion, it is only necessary to call attention to one other matter to show how unjust and discriminating it would be to condemn American fruits on the ground that they contain copper in unwholesome quantities. Brief reference has already been made to the re-greening of vegetables, as practiced by the French. Peas, beans, cucumbers, and similar products are plunged for eight or ten minutes in a solution of copper sulphate in order to fix the natural green coloring matter. After removing the vegetables from the copper sulphate solution they are washed in pure water, placed in jars containing a solution of common salt, sealed and sterilized by heat.

The analyses of such vegetables show that they contain copper in considerable quantity, as will be seen by consulting the table below:

Table showing copper in 1 kilogram of re-greened canned vegetables.

Vegetables.	Authority.	Amount of copper.
		Milligrams.
Peas	Galippe	48 to 60
Do	Carles	70 to 210
Do	Gautier	11 to 125
Beans		49 to 99
Cucumbers	Magnier	2
Tomatoes	Sestini	50 to 354

It appears from the foregoing that vegetables re-greened by the copper process may contain from two to sixty times as much of the metal as sprayed grapes. In other words, if 1,000,000 pounds of sprayed grapes contain 5 pounds of copper, 1,000,000 pounds of re-greened vegetables would contain from 38 to 150 pounds of the metal. Great Britain imported over 14,000,000 pounds of canned vegetables from France in 1890, and it is safe to say that these vegetables contained more than twenty times as much copper as all the sprayed fruit in the United States combined.

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 8.

AGRICULTURAL EXPERIMENT STATION
ILLINOIS

RESULTS
OF
EXPERIMENTS WITH INOCULATION
FOR THE
PREVENTION OF HOG CHOLERA.

BY

Dr. D. E. SALMON,
CHIEF OF THE BUREAU OF ANIMAL INDUSTRY.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., May 7, 1892.

Sir: I have the honor to submit herewith for publication a report upon the results of experiments with inoculation for the prevention of hog cholera.

Very respectfully,

D. E. Salmon,
Chief of the Bureau of Animal Industry.

Hon. J. M. Rusk,
Secretary of Agriculture.

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RESULTS OF EXPERIMENTS WITH INOCULATION FOR THE PREVENTION OF HOG CHOLERA.

INTRODUCTORY REMARKS.

In the following pages is given a review of the efforts which have been made to discover a method of inoculation that would prevent hog cholera, and also a statement of the tests which have been made to demonstrate the value of inoculation. This evidence is given with considerable detail, and an array of facts is presented which should satisfy any reasonable man of the correctness of the conclusions.

It has been apparent for some time that inoculation as a preventive of hog cholera was a failure. But in spite of this it has been advocated by interested parties for their own purposes, and has been indorsed by a portion of the agricultural press in terms which are inexplicable to to those who know the facts. The cases in which inoculation has been performed with little or no loss have been published as proving the success of the operation, while those in which heavy losses have occurred have not been mentioned until the information reached the public in other ways, and then there has been an attempt to explain them away.

It is due to our farmers that they should have all the facts—that they should know all the losses and failures which occur. To hold these back and advocate inoculation is to practice misrepresentation and deception, and to lead farmers to try a method, alleged to be protective, but which is liable to destroy their entire herds and force them into bankruptcy. It has not been a pleasant matter to take up these wrongs which have been practiced on our farmers and to expose them, but they have been carried on with such persistency that this has become necessary.

Inoculation for hog cholera was shown to be of no practical value by the experiments of this Department made in 1886. It proved a failure in the experiments made by the Nebraska Experiment Station in 1888 and 1889. As a private enterprise, there was a failure to carry out the promise to inoculate and to insure the farmer against loss from disease among inoculated hogs. The attempt to establish a business of inoculating hogs at 50 cents a head was a financial failure.

The attempt to protect hogs by inoculation when fed in distilleries was a failure. The attempt to feed hogs on glucose refuse and protect them by inoculation was the most disastrous failure of all, only because it was attempted on a larger scale. The attempt to show the value of inoculation in the Ottawa experiment was a failure. The attempt to protect hogs by inoculation on the State farm of Nebraska was a failure. The inoculations in Nebraska for the year 1891, taken as a whole, are a failure, and have been followed by nearly or quite three times the average loss which has prevailed among uninoculated herds in the State at large. The whole history of inoculation from beginning to end has been a series of failures. It has caused terrible and disastrous losses to farmers who have been led to test it in their herds. It has been demonstrated to be a means of spreading the disease. Its protective influence has never been conclusively demonstrated, but in many cases it has been proved that inoculated hogs were not protected.

Why, then, should farmers practice inoculation as a preventive against hog cholera? Why should they give the time and trouble and expense which it involves? Why should they take the risk of disease, of stunting their hogs, of loss of weight? There certainly can be no reason for their doing this when the losses among the inoculated hogs are greater than those among hogs in the same State that have not been inoculated.

This Department does not recommend inoculation. It believes it to be injurious and unsafe for the hogs operated upon, dangerous to other hogs in the communities where practiced, and that its protective power is uncertain and of very little effect, even if it exists at all.

With the facts and legitimate conclusions given in this bulletin the question of inoculation is left in the hands of the farmers. Those who decide to test it will do so knowing the consequences which are liable to follow. This Department does not oppose inoculation or attempt to prevent its use, but it believes that the farmers should know all the facts in order that they may decide intelligently whether it is to their interest to adopt inoculation or to avoid it.

INOCULATION AS USED FOR THE PREVENTION OF SWINE DISEASES.

Inoculation with hog-cholera virus was first tested as a preventive of this disease in the experiments of the Bureau of Animal Industry in the year 1886. The method of inoculation was discovered at that time, but the results were unsatisfactory, as the animals were not sufficiently protected, and the experiments have been repeated under various conditions from that time to the present to learn if any modification of the operation would make it more effectual.

Prevention by inoculation depends on the well-known principle that one attack of a contagious disease generally protects the individual from subsequent attacks of the same contagion. The amount of protection received varies greatly with different diseases and different animals. In no case are all individuals protected in this way from any disease, and in many cases the immunity lasts only for a short period of time.

Inoculation in practice consists in injecting under the skin as much of the strong virus of hog cholera as can be given without producing a fatal attack of the disease. Inoculation is very different from vaccination. The virus used in inoculation is the same in variety and strength as that found in animals dying with the plague, while for vaccination a weakened virus is used, which can not cause a fatal disease. Although vaccination with attenuated virus prepared in several different ways has been tested in the experiments of the Bureau, no method of successfully preventing the disease known as hog cholera by vaccination has ever been introduced or discovered.

Some breeders have advocated inoculation on the ground that vaccination has been found efficacious in preventing smallpox in the human subject, and that, consequently, inoculation should be an equally reliable preventive of hog cholera. In reaching this conclusion they overlook two very important facts. In the first place there are communicable diseases, such as tuberculosis, from which no immunity can be acquired either from vaccination, inoculation, or an attack of the disease contracted by ordinary exposure. It is therefore impossible to decide such a question by reasoning from one disease to another. The matter of immunity must be determined by observations with each particular disease. In the second place, the effects of inoculation and vaccination are radically different. The vaccine virus, as used in the prevention of smallpox, is not the virus of smallpox, but of a different and distinct disease. It produces a mild disease in cattle and an equally mild disease in people. It never assumes a malignant and fatal character either in cattle or people. For this reason it can be used with safety. Before vaccination was discovered, however, inoculation with smallpox virus was sometimes used, but its results were uncertain and often fatal.

Inoculation is now being advocated as a preventive for hog cholera, and it should be remembered that this means the introduction into the animal's body of the strong virus of the malady, and it is a question of the size of the dose whether the disease produced by this operation is mild or fatal in its character.

The dose is not the only factor which influences the result that follows inoculation. The strength of the virus varies so much in different outbreaks of the same disease that a perfectly harmless dose obtained from one outbreak will be certainly fatal when obtained from another.

There is another influence which has an even greater effect in varying the results of inoculation, and that is the wide difference in the susceptibility of the animals. A dose of virus that will scarcely affect one animal will kill another in the same herd, and there is also such a great difference in the susceptibility in different herds that the dose which might be used on one herd without producing any noticeable effects would set up a disease in another herd and cause the loss of a majority of the animals.

With these varying conditions, which in many cases can neither be foreseen nor controlled, inoculation is an operation which is attended with more or less danger of producing the very disease which we are seeking to avoid. In our experiments we found that a dose of 1 cubic centimeter, *i. e.*, from 15 to 20 drops of the strongest cultivated virus, would occasionally kill an animal. From one-quarter to one-half this quantity, *i. e.*, from 4 to 10 drops, have been given without serious consequences in any case.

Such doses generally produce a swelling where injected, which is at first warm and more or less painful, and later becomes encysted. The center softens, disintegrates, and becomes a purulent mass, which may remain encysted or may force an opening through the skin and discharge for several weeks. An inoculation of this kind produces a slight degree of immunity, because a second inoculation can then be made with 2 or 3 cubic centimeters of virus, *i. e.*, with four to twelve times the first dose, and still no fatal effects result.

The second inoculation increases the immunity, but still the animals are not able to resist the effects of feeding with strong virus or exposure in pens where sick animals are kept. We inoculated about 50 animals in this way in our first experiments, varying the doses somewhat, and only 5 of them resisted the first exposure. By giving two inoculations we of course get a greater degree of protection than can possibly be obtained from one inoculation, with safety to the animals, but the expense of two inoculations is so great that, in order to make the method practical, the inoculator gives only one dose, and generally increases that beyond the limit of safety. Thus, in some experiments that have been made in the West, I am informed that a dose of 1 cubic centimeter, *i. e.*, from 15 to 20 drops, was given, and many herds contracted the disease and died, as should have been anticipated from the experiments previously made by the Bureau of Animal Industry.

In view of these facts, which have been developed by careful and unbiased scientific inquiry, it is scientifically and economically of the greatest importance to thoroughly investigate and consider the evidence brought forward by those who assert inoculation to be a great success before their claims are admitted to be correct.

If inoculation does not protect in a majority of cases from the disease, this alone should be a sufficiently serious objection to prevent its adoption. And if, in addition to a failure to protect, there is a grave danger of stunting the hogs that are inoculated, of producing a fatal form of the disease, and of spreading the contagion to hogs that are not inoculated, then to advocate or adopt this method would be so absurd and preposterous that it could not be expected of sensible and reasonable men.

The question of the value and success of inoculation must, therefore, be decided by an examination of the results of this operation where it has been practiced and tested. It can not be decided by unsupported assertions nor by plausible arguments which ignore the failures and losses, and take into account only the cases where the animals survive the operation.

The question has become a specially important one. Inoculation has been so persistently and unqualifiedly recommended during the past four years by Dr. Billings, of the Nebraska Experiment Station, and he has been so firmly sustained by the chancellor and regents of the University of Nebraska and by a portion of the agricultural press, that the operation has been adopted and practiced on a scale of considerable magnitude. A widespread interest in the matter has been excited, and many farmers are anxiously inquiring whether the claims that have been put forth are or are not well founded.

The general adoption of inoculation by our farmers either means protection from hog cholera or it means great loss from the cost of the operation and the spread of the disease. Whether one or the other of these results is demonstrated to follow the practice, it is the duty of this Department to collect the facts, to consider them, and to present them to swine-growers with the legitimate deductions to which they lead. The time has come when this can be accomplished in a sufficiently complete manner to leave no doubt as to the conclusions which must be reached. An extended correspondence with those who have tested inoculation has brought out many facts of the greatest interest and most direct bearing on the subject. In addition to this an experiment made on a sufficient scale to insure reliable and decisive results, and with every precaution that could be suggested, confirms the conclusion reached from an examination of the practical tests. In fact all the evidence, from the first experiments made by this Bureau early in 1886 to the latest inoculations in Nebraska, is harmonious and points unquestionably to the same general conclusion.

EXAMINATION OF THE CLAIMS AND INOCULATIONS MADE BY DR. BILLINGS, 1887 to 1889.

The chief advocate of inoculation has undoubtedly been Dr. F. S. Billings, of the Nebraska Experiment Station, and when others have advocated this practice they have based their opinions upon his experiments. To fully understand the value and bearing of the evidence brought out by his tests, it is consequently necessary to take them up with some detail and examine them with care.

In the Nebraska State Journal, January 21, 1887, he said:

> Under the auspices of the State University I have been successful in demonstrating that this disease can be almost absolutely prevented by means of artificial inoculation, and we are prepared to make any test that may be desired with the small number of hogs at our command. * * * As it is, we have as sufficiently demonstrated the fact that vaccine prevention is practical and possible, as we have done it in a large number of hogs, for the tests have been far more severe than could possibly occur to hogs in any infection under natural conditions.

In the same paper for January 25, 1887, he said: "All we now need is the means to make one grand test experiment, which I propose to do as soon as the funds you have so kindly asked for are at our disposal."

Being requested to make this experiment by the State veterinarian, in order that the method might be adopted in the field, if successful, by the State live stock sanitary commission, he replied in a long article, from which the following quotation is made:

> I leave it to every practical farmer in Nebraska whether he considers another test necessary to show that prevention by inoculation can be done. Then why is it not practical as well as practicable?
>
> First. Because it stunts the hogs in their growth.
>
> Second. Because the method used consists of a virus which contains the germs or specific cause of hog cholera.
>
> (So long as we use such a virus as that, so long will it be possible for every hog thus inoculated to infect the earth or pens where it is placed, and hence make pestiferous centers where none may previously have existed. As the earth is the natural abode of the germs of this disease, it is self-evident they would again acquire their natural virulence in course of time.)
>
> We have not been engaged to spread this disease, but to prevent it.
>
> These two circumstances were doubtless unknown to the State veterinarian of Nebraska when he suddenly displayed such extraordinary interest in the welfare of the swine breeders of the State. They show the utter folly of continuing this line of experimentation and the test demanded by him.—(Nebraska State Journal, October 9, 1887.)

The above quotation shows that thus early in his investigations the investigator recognized three conclusions as the result of his experiments: first, that inoculation stunted the hogs; secondly, that it spread the disease; and, thirdly, that the method is not practical, and that it is utter folly to continue this line of experimentation.

The experimentation was nevertheless continued, for at the meeting of the National Swine Breeders' Association, November 14, 1888, Dr. Billings said:

> I would say to you that there is no question but that we are eventually going to prevent swine plague by inoculation. My tests are more severe than any that have ever been made by Pasteur or anybody else in the line of experiments, and there has been no failure. This year I received word from my assistants that they have inoculated 1,000 hogs. They would have inoculated more, but I myself am opposed to it for the simple reason that the method does not suit me.

Within two weeks after this public announcement that there had been no failure and that 1,000 hogs had been inoculated, the Breeders' Gazette (November 28, 1888) contained the following statement:

> Mr. H. H. Hess, Surprise, Nebr., writes: "For the interest of the readers of the Gazette I would like to give my experience with inoculation as a preventive of hog cholera. I had Dr. Billings inoculate 260 head of hogs for me, and he just killed all but 40, and they will die. I consider it the greatest humbug ever heard of. My hogs were perfectly healthy when inoculated."

This and other newspaper articles on the subject brought out a statement by the originator of the experiments, from which the following table is compiled:

Name of owner.	No. inoculated.	No. lost.
Surprise, Nebr.:		
D. L. Sylvester	93	73.
Ed. Hinkley	163	No information.
F. W. Luddon	52	None.
L. E. Luddon	46	Nearly all.
H. H. Hess	260	220.
C. W. Walker	11	None.
Gibbon, Nebr.:		
W. A. Rogers	10	
L. C. Bassett	22	
H. A. Lee	154	
Humphrey & Harris	34	
D. P. Ashburn	18	
Lincoln, Nebr.:		
State Farm	30	
Falls City, Nebr.:		
Mr. Steele	121	Large number.
Total	1,014	

Mr. Walker has since stated that in L. E. Luddon's herd all but 6 died, and that some of Mr. Hinkley's were lost, but the number was not given. An article in the Omaha Bee at the time stated that Mr. Steele lost 110 within thirty days. Mr. Hess states that his total loss was 240. This would make the loss from the information at hand 463 out of the 1,014 inoculated, or 45½ per cent. This does not include Mr. Hinkley's loss, which is unknown.

When it is considered that the experimenter had asserted for nearly two years that he could prevent the disease by inoculation, that during this time the question had been contested and he had been perfecting his method, and that these experiments were made to demonstrate the value of the method, such a complete and disastrous failure in the results is certainly surprising. Under such circumstances it is self-evident that more than ordinary care would be observed in preparing the virus, and in having the conditions as favorable as possible for success.

An attempt has been made to explain these losses on the theory that the herds were infected before they were inoculated, and that the inoculation had nothing to do with the production of the disease. It is said that in one herd several had died before the inoculation; that the two Luddon brothers, who were among those that inoculated, lived side by side, the road only separating their dooryards; that their hogs were inoculated at the same time and in every particular alike, using virus out of the same bottle, yet not one out of the larger herd sickened perceptibly, while with the other herd all but six died; that another brother had a dozen or more hogs that were not inoculated and were kept in a tight pen on the premises with the latter herd, to which they were in no way exposed, "but simultaneously with them sickened and died in about the same ratio." From this it was argued that no poison could work that way, "fatal or harmless according to the side of the highway on which it was administered."

In considering this explanation, we can not lose sight of the fact that the virus of contagious diseases is exactly the one poison which does act in an unequal and apparently erratic manner. When a roomful of school children are exposed to one of their number affected with measles or scarlet fever, every child does not contract the disease, though all are equally exposed. The children of some families will contract the disease, while those of other families will remain free from it. This is not the result of living on different sides of a street or in different parts of a town, but it is due to the difference in susceptibility, which varies both with individuals and with families.

The observation of natural outbreaks of hog cholera also shows that, with animals equally exposed, some will contract the disease and die while others will be unaffected. Of two herds in adjoining fields one may be affected and the other remain healthy. In the same herd the young pigs may all die and the older hogs may not show signs of disease. Such observations, repeated in innumerable instances, are sufficient to demonstrate that the action of the virus of contagious diseases can not properly be compared with other poisons. A poisonous dose of strychnine will affect all animals of the same species and size in substantially the same manner. The same dose of hog-cholera virus may kill a portion of the animals to which it is administered, while the other portion may show no effects from it. In the experiments made by this Bureau concerning inoculation this has been incontestably demonstrated. A few examples will illustrate this.

Of 4 hogs inoculated with 1½ cubic centimeters each, of culture liquid, 1 died in seven days, 1 in eleven days, and 2 survived.

Of 8 hogs inoculated with one-half cubic centimeter each, of culture, 1 died in six days and the remainder survived.

Of 16 hogs inoculated with a like dose of the same culture, 1 died and the rest remained well.

Of two lots of hogs containing 21 and 27 animals respectively, and together exposed to the same contagion 4 died from one lot, and none from the other.

Of two lots of hogs containing 16 and 14 respectively, and together exposed to the same outbreak of disease, the larger lot resisted, while 11 of the 14 in the other lot died.

These instances are sufficient to show the unsoundness of the argument that because a part of the herds resisted, the others could not have contracted the disease from the inoculation.

To determine whether the disease was produced by the inoculation, the most important evidence is the time at which the first sickness was observed in the inoculated herds. If about the usual period of incubation elapsed after inoculation before sickness or deaths occurred, that is a very strong indication that the disease was caused by the inoculation. If there were deaths in one herd before the inoculation was performed that herd should be left out of consideration. Unfortunately, no clear statement of the facts has been made to the public by the inoculator, and what has been written is conflicting and contradictory. At the meeting of the National Swine Breeders' Association above referred to it was stated that no failure had occurred. Afterwards it was stated that about 400 had died, but that this was not the result of the inoculation. Still later it was stated that over 1,000 hogs had been inoculated in Nebraska since 1886, most of which had been exposed and reëxposed to infection in very severe outbreaks of the real swine plague, with a reported loss of but 11 hogs out of the whole number.*

It has not been asserted that there had been any sickness among L. E. Luddon's hogs before inoculation. It is only said that his brother's hogs, across the road, did not become sick, and that another brother's hogs, on the same premises, sickened simultaneously and died in about the same proportion. This proves nothing. As has already been shown, one lot of hogs may resist an exposure that will be very fatal to another lot. If the date of inoculation and the date of the first death in the lot of 46 had been given, as well the first death among the hogs in the pen, this would be a better indication from which to judge. But this information has never been given.

What is meant by the two lots sickening simultaneously? Was the first sick animal in each lot observed within the same hour, the same day, or the same week? This makes an important difference. If they were observed the same day it would not show that the disease was not the result of the inoculation. In making an inoculation the owner is liable to infect his clothing and to carry the contagion on that or on his shoes to another lot of hogs on the same premises. If the first sickness or death occurred between five and thirty days after inoculation, it probably was caused by the inoculation. That is as much as can be said.

If this were the only herd that sickened out of a large number we should be disposed to admit that the infection was accidental. But if, on the other hand, it can be shown that disease in other cases has frequently followed inoculation, and that the sickness appeared from five to thirty days after the operation was performed, it would not be logical to conclude that this was, in all such cases, an accidental coincidence, and that the inoculation was harmless.

Fortunately, we have the facts in regard to the largest herd inoculated at that time. The owner in reply to an inquiry made the following statement:

SURPRISE, NEBR., *February 2, 1892.*

SIR: Yours of the 28th ultimo received, and I will try and give you my experience with inoculation. The fall of 1888, some time in October, as near as I can remember, Dr. Billings, of Lincoln, sent Dr. Thomas here to inoculate my hogs, which numbered 260. In about eight or ten days after they were inoculated they all took sick. Within four weeks 230 died, and between that time and spring 10 more died. Only 20 survived out of 260.

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* Prevention of Swine Plague by Inoculation. Frank S. Billings & Co., p. 5.

My hogs were perfectly healthy when inoculated.

That, in brief, is my experience. If Dr. Billings had not been indorsed by the State I should never have allowed him to inoculate; but he had stated in a lecture that it was no more an experiment, but a settled fact; that it was a preventive. I do not believe that making the virus out of a cholera hog and putting it into a heathy hog will work.

I could not recommend inoculation.

Very respectfully,

H. H. HESS.

Hon. J. M. RUSK.

The following correspondence, brought out by a circular of inquiry from this Department, shows that many herds were inoculated during 1888 and 1889, and that many losses from inoculation occurred during those years, of which the public, up to this time, has had no information. They also indicate most emphatically that the sentiment among the farmers in the districts where inoculation has been most thoroughly tested is overwhelmingly against the practice.

Dr. H. N. Hall, Ayr, Adams County, Nebr.:

The last outbreak of hog cholera in this vicinity was in 1889. Two herds were inoculated. One belonged to W. Lowman, of Hastings, Nebr. The owner says 1 died while testing it, and the rest never did well and were hard to fatten. The other herd contained 10 animals, and in this none died from inoculation. The popular opinion on inoculation in this part of the State is not very favorable. We are waiting for a chance to test it more thoroughly.

Edward Creager, Juniata, Adams County, Nebr.:

Inoculation has been practiced to a certain extent. It was tested in four herds that I know of, an average of 5 in each herd being inoculated. I can not say positively how many deaths occurred before thirty days or how many afterward, but most of the deaths occurred before that period had elapsed. I would not recommend inoculation.

J. W. Coulter, Hastings, Adams County, Nebr.:

Inoculation has been practiced in this vicinity, and particularly in one herd of about 300 head; the number in the other herds not known. In the large herd a few died in about twelve to fifteen days after the inoculation; exact number not known. I am a strong believer in inoculation, but I would advise care in its use. All the hogs on the place should be inoculated at one time that have not been previously inoculated. Everything said in regard to this should be taken with a grain of allowance, for in 1883, 1884, and 1885 my neighbors' hogs had the cholera and large numbers of them died, and mine were not affected, although they frequently intermingled. I thought this was because I treated my hogs somewhat differently, and that I had found a preventive for the cholera, but in 1886 my hogs nearly all died.

D. N. Miller, David City, Butler County, Nebr.:

Inoculation was practiced in the western part of Butler County in 1888. Eight or ten herds were inoculated. I would not recommend inoculation.

John H. Sleeger, Surprise, Butler County, Nebr.:

Inoculation has been tried in this vicinity. Mr. H. H. Hess, of Surprise, had inoculated a few years ago 260 head, and 230 died directly from the effects of inoculation, so the owner stated. Ed. Hinckley, also of Surprise, had several hundred treated, and a great many died. Wilbur Ludden tried it with the same results; also his brother, L. Ludden, all of Surprise. I am not able to give you the number in any of the herds except that of Mr. Hess. I never tried inoculation, although I lost nearly all my hogs a few years ago. About the only man in this neighborhood that believes in the treatment is C. H. Walker, of Surprise. He and Dr. Billings were going through the county doing all they could toward it, but I do not know of anyone trying it since the men above named failed.

Lewis E. Talmage, of Surprise, Butler County, Nebr.:

In reply to yours, will say the last case that I know anything about was that of D. L. Sylvester, of Surprise. In the fall of 1890 he had 75 inoculated, and then sold them to Mr. C. H. Walker, of Surprise, to ship to Iowa. I do not know the percentage of deaths resulting from the inoculation. Miller Brothers, of Surprise, in 1890, had some 70 inoculated, and lost almost the entire herd. They also had a bunch inoculated in 1888 and lost a large percentage. Mr. Christ. Schroder, of Surprise, had 250 inoculated, and he told me he lost nearly the entire herd, and the few that did live were damaged. Mr. H. H. Hess, of Surprise, inoculated in 1888 probably 200 head, and lost 90 per cent. Wilbur and Charles Ludden, of Surprise, the same fall inoculated with the same results. The number of hogs given in each case is from memory.

D. P. Ashburn, Gibbon, Buffalo County, Nebr.:

Inoculation has been practiced in this vicinity by 6 or 8 persons having from 30 to 200 animals in a herd. With one single exception none were lost. H. A. Lee, of Kearney, lost 3 or 4 head out of a pen of 24 that were closely confined and had only dry corn and water to eat. He also inoculated about 125 that were running after cattle in a field or large corral at the same time and with the same virus, and the effect was not noticeable. None died or were sick. I would recommend inoculation in careful, intelligent hands, but not otherwise. It creates a mild case of cholera, from which the disease will spread if not prevented, and as the average hog-raiser is not to be relied upon in this particular, I think for general use as a preventive it would be likely to create as much loss as it would prevent. I have used it for several succeeding years with success, and if I again raise hogs shall use it if nothing better offers. I am impressed with the great need of a safer virus, and think it possible that scientific research might discover it.

John Reddy, Gibbon, Buffalo County, Nebr.:

In answer to your inquiries I must say none of my hogs were inoculated, but my neighbors put 8 hogs in my yard as a test that were inoculated by S. C. Bassett, the agent of Dr. Billings, of Lincoln, Nebr. Seven out of the 8 died of cholera, and the 1 that lived had a slight touch of it, but recovered. A very poor showing, as we all thought, since a greater per cent. of my hogs lived that were not inoculated at all.

S. C. Bassett, Gibbon, Buffalo County, Nebr.:

A few hundred hogs were inoculated in this vicinity in the years of 1888 and 1889. A less number were inoculated in 1890 and 1891. According to my recollection, seven herds were inoculated, containing from 20 to 150 head in a herd. In the majority of these herds—five, as I remember—none of the inoculated hogs died within thirty days. In the other two herds, 3 in one herd of 20 inoculated and 7 in one herd of 150 inoculated died. These experiments were mostly confined to pigs ranging from six weeks to three months old. Five of these inoculated pigs were placed in a herd suffering from one of the most fatal outbreaks of cholera I have ever known, and 3 of said pigs died. On my own farm, I inoculated hogs first in the spring of 1888, and with one exception have inoculated all pigs farrowed on the farm since that date. I have had no hogs die from the effects of inoculation; neither have I had inoculated hogs die with hog cholera. From my observation and experience I am strongly of the opinion that of hogs inoculated by the Billings method as now practiced a large per cent may be prevented from contracting the disease hog cholera. I am positive that inoculation by this method does not kill, does not stunt, does not injuriously affect the hog. Its effects are hardly perceptible to those who care for hogs.

C. Dean, Gibbon, Buffalo County, Nebr.:

I can not tell just how many herds or the number of animals in each herd that were inoculated. Inoculated hogs died in all the herds so far as I know, but can not state the number. It has not proved to be a preventive for hog cholera in our part of the country.

William Welland, Gibbon, Buffalo County, Nebr.:

Inoculation has been practiced in this vicinity in seven or eight herds, from 25 to 200 in a herd, in past years. None in 1891. In one or two instances 3 or 4 head died. In several instances hogs have been taken from inoculated herds and exposed. They stood the test where the inoculation was properly done. I would not recommend inoculation in its present condition. I believe the practice and principles are right and will prevent disease, but the great liability of spreading disease by inoculation in careless hands is too great to make its general use practical. What is needed is virus that will produce the effect without starting the disease.

W. J. Davis, Fort Robinson, Dawes County, Nebr.:

Billings's inoculation has been tried in some neighborhoods. I think about six herds and about 10 in each herd. I only heard of 2 that died out of the total number. I would recommend inoculation.

R. M. Allen, general manager of the Standard Cattle Company, Ames, Dodge County, Nebr.:

We have practiced inoculation ourselves, but do not know of any other person in this county who has practiced it. We inoculated, June 9, 1889, 54 hogs; August 1, 1889, 143 hogs; and we inoculated 8 head of sucking pigs about April 1, 1891. In our first experiment 4 head died out of 54 within thirty days. In the next experiment, August 1, 1889, a violent outbreak occurred, destroying all but about 30 out of 143. The last bunch of 8 head were all sucking pigs, and died soon after inoculation. I am not able to say whether they died from the inoculation or not. The second lot of 143 were slightly infected with cholera at the time of inoculation. The outbreak which started August 7 lasted longer than thirty days. I would not recommend inoculation from my personal observation of its effects, but from my experience with hog cholera I recommend its trial in a very careful, systematic, and guarded manner by such farmers as are intelligent enough to practice it themselves. I think it is likely that the number of hogs that will survive outbreaks of cholera will be greater if inoculation is practiced, especially if practiced at several different times on the same subject.

B. W. Reynolds, Fremont, Dodge County, Nebr.:

So far as my own information goes, I am led to believe that Dr. Billings's inoculation process for the prevention and cure of hog cholera is a failure in the majority of cases. I know, however, that by adopting advanced ideas as to sanitary conditions, and adhering to them, hog raisers in this county are suffering less than formerly.

J. O. Milligan, Scribner, Dodge County, Nebr.:

The few experiments in inoculation made in this section did not prove very satisfactory. From my observation of its effects I would not want it practiced on my herd. As far as I know personally that method of treatment not only proved fatal to the hogs inoculated, but caused the disease to spread.

G. Abell, Exeter, Fillmore County, Nebr.:

A neighbor of mine, William Sullivan, of Cordova, Seward County, had some of his hogs inoculated. I went to see him this morning. He inoculated between 20 and 25. He had on his farm probably twice that number. Three or 4 of the smaller ones died. There being no disease in the neighborhood at that time, he hardly considers it a fair test of prevention.

Hugh Gibson, Fairmont, Fillmore County, Nebr.:

I know of only 3 men that have tried inoculation. One herd had 50 head; all died. One herd had 65 head; 35 died. The other herd of 30 head all did well. All the deaths occurred twenty to twenty-five days after inoculation. Would recommend inoculation when the animals are two or three months old. After they get older I do not think it is successful.

John Sheridan, Grafton, Fillmore County, Nebr.:

I know of three herds that were inoculated, varying from 40 to 60 head in each. In two of them none were lost, while in the third herd about all died. I have no faith in any remedy, inoculation included. As far as these two herds are concerned I think it no proof that they were protected from the cholera. One man purchased 15 head soon after inoculation; they are all right. There are several herds that have not been inoculated and escaped the cholera. I had 130 in my herd. They got the cholera. I tried all the so-called sure cures to no effect; then changed them around to a different part of the farm in different lots, grading them according to their appearance. I think that saved 24. There was a bunch of hogs within 60 rods of mine that were not inoculated, and they did not get the cholera.

H. C. Stoll, Beatrice, Gage County, Nebr.:

Two years ago I had 23 head inoculated by Billings's man, and all died within twenty days. I have been told that Mr. Billings had a large hog ranch at Davenport, Iowa, where he bought several hundred hogs and inoculated them; but cholera hogs came in contact with them, and then they all "went up the spout." A man told me that was there and saw them. I most decidedly would not recommend inoculation, unless the operator first pays for the hogs. Three years ago my hogs contracted the disease at the St. Louis fair, and I lost over $5,000 worth. I then bought 23 head of fine sows, all in pig. I had a talk with Billings, and he told me to inoculate them. I told him I was afraid, because they were all in pig. He said it would not hurt them on that account. He sent a man who inoculated them. The next week he came again and repeated it. The result was that all died. The same man inoculated two herds in Iowa, and they died. When I told Billings the result, he sent out pamphlets stating that sows in pig should not be inoculated. He should have known that at first. But 2 or 3 died that were not in pig. I had a long talk with one of his men, and he said it was a good thing if 10 per cent were saved by inoculating them. I do not want any preventive that will save only 10 per cent when I can save 50 per cent after they get the disease.

G. D. Mullihan, Paddock, Holt County, Nebr.:

Near Creighton, where I formerly lived, there were some hogs inoculated, and there are various opinions as to its preventing cholera, but the majority are not favorable to it as near as I can learn.

Francis C. Urban, Little, Holt County, Nebr.:

Inoculation has been tested in two herds in this vicinity. In one herd of twelve, 8 were inoculated and 6 afterward died. The other herd contained 28 head, of which 22 were inoculated, and 25 afterward died. From what I have seen I would not recommend inoculation. These herds were inoculated according to the Billings method by a veterinarian from Lincoln, Nebr.

C. F. Sodman, Elk Creek, Johnson County, Nebr.:

My neighbor had 10 hogs inoculated out of a herd of 25, and another had 5 inoculated out of 20. All the inoculated hogs in the first herd died, and part of those not inoculated. In the second herd no hogs died. I would not recommend inoculation.

C. M. Branson, Lincoln, Lancaster County, Nebr.:

The State prison tried inoculation, and an extensive feeder of cattle and hogs tried it. It was done by Dr. Billings. There were two herds—I think about 50 in each herd. Nearly all died in one herd, and I think none in the other. Some who have had hogs inoculated have told me that they were highly pleased with it, and say they would not risk having hogs without inoculation. Dr. Billings has often assured me that it is a wonderful preventive. I know nothing of my own experience.

H. B. Musser, Lincoln, Lancaster County, Nebr.:

I have only learned of a few herds that were inoculated. In one a part were inoculated; in the others, all. I do not know the number which were afterward lost, but the greater part died. I would not recommend inoculation.

E. F. Black, Raymond, Lancaster County, Nebr.:

Only one herd in this vicinity has been inoculated. This contained but 3 animals, and 1 out of the 3 died. There has been a great deal of inoculation in this county by Dr. Billings and his assistants, but reports are very conflicting as to the results.

James W. Eaton, Nebraska City, Otoe County, Nebr.:

I only know of one herd that was inoculated, and they were evidently infected before the operation. This herd belonged to John Campbell, of Nebraska City. His neighbor, Simeon Patton, has a hog-yard just across the road, 4 rods distant, both being mostly in a low swale. Mr. Patton's hogs had cholera, and were dying fast when Mr. Campbell got the virus and inoculated his own hogs. Mr. Campbell inoculated 20 large hogs and 65 pigs or young hogs. Of the large hogs, 19 were kept at some distance from the others and from Mr. Patton's. None of these showed any indications of being sick. The other large hog, being lame, was kept with the pigs. He died, and so did 60 or 61 of the shotes out of the 65 inoculated. The shotes got sick in six or seven days after treatment and died soon afterward. Mr. Campbell does not believe in inoculation.

Fred. Lucas, Unadilla, Otoe County, Nebr.:

The cholera is as it has always been. I have had it on my farm about six times, but not during the last three years. The last year it paid us a visit in January, and took all but 12. An outbreak the June before left about 25. My neighbor did not have the disease at any of the times when it visited me. All there is between his hogs and mine is a common board and wire fence. Now, during the last twelve months, when my farm has been free from it, it has taken his hogs. It singles out one man, and takes almost all his hogs, while his neighbor goes free. Mr. W. Rotton, of Unadilla, had about 50 head which were inoculated. After about three months he sold 8 to Mr. Avery, who had the disease some three or four months before and lost nearly all of his hogs. Of the 8 inoculated hogs bought, he put 7 in the yards that had the disease in them some months before. One was taken away to other lots. The 7 all contracted the disease in a severe form. Three died; the other 4 eventually recovered. The other 1 never took the disease nor was exposed. I have no faith in inoculation or anything else to prevent this disease.

A. E. Lane, Table Rock, Pawnee County, Nebr.:

There were two herds inoculated in this neighborhood in February, 1890. One herd was owned by D. K. Miller. It consisted of 9 animals that had been purchased by him for the experiment, and they were supposed to be free from disease. They were inoculated by S. C. Bassett, one of Dr. Billings's agents. Eight of the 9 died within thirty days after their inoculation. Herd number 2 consisted of 13 animals. They were inoculated by the same man with virus from the same bottle as the first herd mentioned. Six of the 13 died.

Byron Street, Phelps, Phelps County, Nebr.:

A herd east of here was inoculated. About 10 or 12 per cent died from the inoculation. After a time the herd was taken into a yard where other hogs had the cholera in its worst form. Part of the inoculated hogs sickened, but none died.

John W. Tohman, Danbury, Red Willow County, Nebr.:

Two herds that I know of have been inoculated. They belonged to C. Underwood and P. P. Wright. One herd contained about 100 head, and there were 4 or 5 of them died in a few days after they were inoculated. I do not know the number in the other herd. The owners of both of these herds claim that the animals have since been exposed and no further losses have occurred.

John Tighe, Humboldt, Richardson County, Nebr.:

The parties that I know who had hogs inoculated in this county are Wesley Hummel, Dr. J. G. Cox, M. Hardy, and Fred Lewis. Mr. Lewis did the inoculating with virus furnished by Dr. Billings. I can not now say how soon after inoculation any of these hogs died, but the general impression is that it is worthless as a preventive. I do not know of a man in our county that is in favor of it. I would not inoculate my own hogs from what I understand about the way that it has acted on the hogs in this county.

John Lichty, Falls City, Richardson County, Nebr.:

Two herds were inoculated in this vicinity by Dr. Billings. Nearly all died.

John M. Brockman, Humboldt, Richardson County, Nebr.:

My neighbor, Dr. J. G. Cox, had his herd of hogs inoculated, and lost nearly the entire herd. I think the inoculation caused the disease in this herd. Inoculation has been a total failure as a preventive of hog cholera in every instance that has come under my observation.

Isaac N. Ewalt, Falls City, Richardson County, Nebr.:

Prof. Billings, of the State University, inoculated about one-half of a herd for a man in this neighborhood, and about half of them died within thirty days. This is the only herd inoculated in Richardson County that I am aware of. I would not recommend inoculation, as I have but little faith in it. I saw Mr. Steel the other day. He is the man who owned the herd inoculated here. I asked him his opinion, and if he could recommend inoculation. He said he did not know whether it was a preventive or not, as the disease was in his herd when they were inoculated, and there were as many of them died that were inoculated as of those that were not.

P. O. Avery, Humboldt, Richardson County, Nebr.:

Mr. F. L. Lewis inoculated about a dozen herds about a year ago. The herd of Dr. J. G. Cox, about 30 head, all died, or nearly all, within about two weeks. Mr. Lewis inoculated his own herd, about 25 in number. They recovered all right, and were feeding up and doing finely till about sixty days after being inoculated, when they took sick, and all, or nearly all, died, seldom living over four days after getting sick. Mr. John Holman had 25 head inoculated, which he kept on the place where he lives. After about two months he moved them to another farm where he had quite extensive feed lots, and where he had put about 80 shotes that he had just bought out west where crops had failed, and they had no cholera. The latter took sick very soon and all died but 2. None of the inoculated hogs died. The inoculation was made according to Dr. Billings' method.

Charles Neely, jr., Humboldt, Richardson County, Nebr.:

I only know of five or six herds that have been inoculated. Two herds have lost severely after inoculation. From my very limited knowledge of inoculation, I am not very favorably impressed with it.

A. Tynan, Stella, Richardson County, Nebr.:

Inoculation has been tried, but deemed useless, and is no longer practiced. In one herd 75 were inoculated, and all died. Those that were not inoculated lived. I would not recommend it, for in every case I know of it was a failure.

J. S. Wilcox, Morse Bluff, Saunders County, Nebr.:

Lyons Brothers, of Lyons, Burt County, Nebr., had 20 head inoculated in 1889 by Mr. Courtney, of Lincoln, Nebr. These were placed with sick hogs at Mr. Hall's thirty days after inoculation. I went on purpose to see this lot, and have a letter from Mr. Lyons saying that he lost more than three-fourths of them; also that several of his neighbors who were testing inoculation lost theirs. Mr. Courtney claimed that the virus was not right, and proposed to make further test and guarantee the hogs. This proposition was accepted, and the hogs died again this time. Mr. Courtney has not paid for the loss as he had agreed.

C. E. Ward, Belvidere, Thayer County, Nebr.:

I know of one herd that was inoculated in 1889. It belonged to J. H. Horneday. The herd contained 30 hogs, which were inoculated July 10. Twenty-seven died before August 15.

J. M. Bennett, Hebron, Thayer County, Nebr.:

I began inoculating in November, 1889, since which time there has been no disease among my hogs. I once put 3 inoculated hogs in a sick bunch. Two died; the other was affected but did not die. This is the only test I have had opportunity to make.

E. T. Pliefke, Gresham, York County, Nebr.:

I do not know of any inoculated herds that have been exposed to hog cholera and have not afterward suffered from the disease. Mr. Samuel F. Weaver, of Ulysses, Butler County, Nebr., had a herd of 79 inoculated. These were exposed two weeks after, and all died but 13. As far as I have noticed, it avails nothing. One herd of 48 were doing well when inoculated, and in a week began to get sick and die.

E. J. Currier, Harlan, Shelby County, Iowa:

In the fall of 1889, November or December, F. S. Billings, by his agent, Mr. Courtney, inoculated 133 young hogs for me. The inoculation was repeated about sixty days after. Between one and two months after the hogs began to sicken, and about 70 of them died. I sent 21 to another farm, and after they had been there a month they took the cholera and gave it to the healthy hogs already on the place. There was no other case of cholera in that region, and my neighbors were not losing any at the time mine were sick. Did inoculation do it? It looks like it. At any rate, I shed no tears because Billings has shut off the supply of virus for all outside of Nebraska.

The following extracts from letters received by Frank S. Billings & Co., and published in pamphlet No. 3 on inoculation, are also of interest in this connection:

Thos. L. Peifer, Lincoln, Ill.:

Out of the 42 head (of which 25 were pigs, and of which 4 of the latter died and 1 of the large hogs, since inoculating), my hogs have done exceedingly well; they appear healthy, but I can scarcely attribute this to inoculation, as there has been no disease in the immediate neighborhood, so that the preponderance of evidence would not prove much yet with me.

H. A. Lee, Kearney, Buffalo County, Nebr.:

About the 20th of October, 1888, I had 154 pigs inoculated as a preventive of hog cholera. Twenty-four of the above number were at my home farm, and the balance, 130 head, were 2 miles distant, at the stock ranch and feed yards.

During the two years previous to this I had lost the larger part of my pigs during the late fall and winter with cholera, and believing the yards to be thoroughly infected with the disease I concluded to try inoculation as a preventive. No cholera has made its appearance on my farms since.

As to its immediate effects, I will say that the 24 head at the home farm, whose feed was principally corn, were most of them affected, over one-half showing cholera symptoms. Some of them did not get over it for weeks, and one died. The 130 head up to the time of inoculation had been kept almost entirely on oats, and the inoculation produced no visible effect on them.

On the 24th of October, 1889, Mr. Bassett inoculated 143 head of pigs; 137 of them were at the cattle ranch and 6 small runty pigs at the farms. The operation produced no visible effect on the 137, but of the 6 head at the farm 4 died.

On the 8th of December, 1889, I took 4 of the 137 and placed them with the hogs of John Reddy, of Gibbon, whose hogs were dying with the cholera. One took the disease and died; the other 3 are still at his farm, and the last time I saw them seemed healthy and were doing well. On the 28th of December last Mr. Bassett came and wished to reinoculate those which he had before inoculated, saying he feared the virus used on the 24th of October had lost its protective principle. About 135 head were reinoculated; over half of them were sensibly affected, ceased growing, and lost flesh, and there are fully 40 head that have not yet recovered from the effects of the last operation.

C. S. French, Chapin, Ill.:

With me inoculation has not been the success that I hoped it would be. The first lot of 74 did fairly well; 2 died soon after the operation, and 1 disappeared; do not know whether he died or not. One of that lot died a few days ago; he drooped around a few days with outward symptoms of cholera. The rest seem all right of that lot.

The last lot of 27 I would pronounce a perfect failure. They never seemed to get over the operation. They keep running down until they die. There has more than half of them died, and I think more of them will die yet.

PROTECTION BY INOCULATION.

We will now turn for a moment to the question of the protection by the operation. To what extent were the hogs inoculated in Nebraska protected from the contagion if really exposed to it? The advocates of inoculation tell us that it has been impossible for them to give the disease to their inoculated hogs. The letters quoted above show that in several cases the inoculated hogs contracted disease when they were exposed to it in about the same proportion as those which had not been inoculated. John Reddy reports 8 inoculated hogs exposed, all of which became sick, and 7 of which died. S. C. Bassett reports 5 exposed, of which 3 died. Fred Lucas reports 7 exposed, all becoming sick and 3 dying. P. O. Avery reports a herd of 25 which took the disease sixty days after inoculation, and three-fourths of which died. J. M. Bennett put 3 inoculated hogs with sick ones; all took the disease and 2 died. E. J. Currier had 133 hogs inoculated; sixty days afterward they were inoculated the second time, and from this inoculation contracted the disease and 70 died. Our experiments at Washington show that nearly all inoculated hogs can be afterwards fatally infected with cholera. Did the animals inoculated in Nebraska receive any greater degree of immunity than those which were inoculated in Washington? These tests indicate that they did not.

The board of inquiry appointed by the Commissioner of Agriculture in 1888 procured a number of hogs that had been inoculated in Nebraska (about 17), and tested them by feeding them with cultivated virus of hog cholera and by inoculating them with the virus of hog cholera and swine plague. In each case a number of animals that had not received the protective inoculation were used in the experiments to determine the effect of exposure upon ordinary swine. The first test was made by feeding cultivated virus, but this did not prove strong enough to kill any of the hogs. Even those which had not been inoculated survived, but all of the hogs, including those that had been inoculated, were very sick. The inoculated hogs were not quite so sick as the others, but there was very little difference. Four of the inoculated hogs from Nebraska, and 5 hogs from Pennsylvania, which had not previously been inoculated, were then inoculated with the virus of the disease known as infectious pneumonia or swine plague. Of the 4 Nebraska inoculated hogs 3 died and 1 recovered, but this one when subsequently killed for examination proved to be very severely affected. Of the 5 hogs which had not been previously inoculated 1 died and 4 were sick and recovered. When killed for examination one of the 4 was found seriously diseased; the other 3 were either slightly or not at all affected.

Still later, 4 Nebraska inoculated hogs and 2 other hogs which had not been inoculated were fed upon the viscera of hogs which had died of hog cholera. Two of the inoculated hogs and 2 that had not been inoculated contracted hog cholera and died. Two of the inoculated hogs remained well.

As a last test the remaining 6 animals from Nebraska were inoculated by intravenous injection of the cultivated virus of hog cholera. Of these, 3 had been inoculated with hog-cholera virus, and 1 had been inoculated with the sterilized liquids in which hog-cholera germs had grown, and 2 had recovered from an attack of hog cholera. The 4 hogs which had received the protective inoculation all died. One of the recovered hogs died, and the other resisted the virus and remained well.

It is quite evident from these experiments that the animals inoculated in Nebraska were fully as susceptible to hog cholera after the operation as were those which had been inoculated in the experiments of this Bureau in Washington.

The conclusion that inoculation is not a satisfactory preventive for hog cholera is by no means inconsistent with the results obtained in investigating other diseases. Various experiments have shown that the protection which follows one attack of a disease or which is produced artificially by inoculation or vaccination is by no means absolute. It is simply an increased power to resist that particular contagion, and it may be sufficient to guard against the small doses of the virus which with most diseases are all that an animal is exposed to under ordinary conditions. But if from any cause a larger quantity of the contagion finds its way into the animal's body it will contract the disease in a fatal form in spite of the immunity derived from a previous attack or from inoculation. This was strikingly shown in the writer's experiments with fowl cholera (Report Department of Agriculture, 1881–'82, p. 289) and by the researches of Prof. Chauveau with anthrax. While, therefore, it may be perfectly practical to prevent by inoculation those diseases in which the contagion does not multiply outside of the body, and with which the attack is caused by a small quantity of virus floating in the air or adherent to the woodwork of buildings, it may be much more difficult or impossible to prevent that other class of diseases to which hog cholera belongs, and which are caused by germs that multiply freely in water, in the soil, and in moist organic matter, and which are consequently taken into the body in enormous quantities, especially by swine.

This brings the history of the attempts to prevent hog cholera by inoculation down to the year 1889. In that year Dr. Billings resigned his position in the Nebraska Experiment Station and established a laboratory in Chicago for inoculating hogs as a private enterprise. Some of the experiments mentioned in the letters published above refer to inoculations made with virus from this laboratory. As it was not possible in all cases to decide whether the virus was procured from Lincoln or Chicago, and as at both places it was prepared by the same individual, the letters giving the experience of swine-growers have been inserted together in the report.

INSURANCE OF INOCULATED HOGS.

When the laboratory at Chicago was about to commence operations, the impression given out was that the owners of inoculated hogs were to be insured against losses. The following appeared editorially in the Farmers' Review, April 10, 1889:

> His newest departure is one that will doubtless create a furore of excitement in the ranks of the veterinary fraternity of the country, and indeed among the agricultural community likewise. The Billings Live-Stock Insurance Company has, we understand, declared its intention of doing business on a mammoth scale, and before many months pass will have received its final papers. This will be no clap-trap concern, founded on the visionary lines of heretofore live-stock insurance companies, which have accepted risks against death from disease and accident, and brought ruin to all concerned—excepting, of course, the sharpers running the scheme. Hogs will be insured against death from cholera on condition that the animals are inoculated with virus of the disease prepared at the laboratories of the company, which it is proposed to erect and provide with the best bacteria-poison chemist in the world, regardless of cost.

In the Nebraska State Journal, May 2, 1889, Frank S. Billings announced over his own signature that:

> As regards my own experience with inoculation, there are a large number of farmers who have now made the necessary practical tests extending over a period from June, 1888, to the present time, aside entirely from my own, but what is perhaps more conclusive proof than any other is that I am prepared to "take my own medicine" and suffer the consequences.
>
> There is a practical expression that "money talks," and my money and that of my friends will be ready to talk to the amount we may lose from hog cholera against which we are going to insure, on condition that we inoculate the animals first, and as we intend to be ready to "talk" to the tune of half a million or over, and as those interested with me are "in for the dollars," while I am in because I can not serve my country and race in any other way, under the ruling method in American politics, and as these gentlemen have investigated the preventive inoculation experiments in Nebraska, and are satisfied and anxious to go into business on that basis, it does not seem that preventive inoculation needs the indorsement of the chief of the bureau of animus intensified.

These representations having been publicly made, a number of swine-growers applied to have their hogs inoculated and insured against loss, but in every instance that has been brought to our attention the projectors of the enterprise declined to insure the animals. In pamphlet No. 3, on Inoculation (p. 56), issued by Frank S. Billings & Co., it was stated:

> It must be distinctly understood that we do not warrant or guarantee anything. As in vaccination the owner must accept the results, whatever they may be.
>
> No one but an arrant fraud and quack would warrant or guarantee that which neither he nor anyone else can invariably control.

Why this sudden change of policy? If no one but an arrant fraud and quack would warrant or guarantee against loss after the company was formed, was not the same true when the announcement was made in which insurance was to be a prominent feature of the company's business? Is it not probable that the losses following inoculation were found to be too great to admit of profitable insurance, rather than that the inoculator had so suddenly experienced a radical change of sentiment in regard to the propriety of insurance in such cases? The letters given in this report detailing the heavy losses in Nebraska, losses which have never before been made public, indicate that insurance would have been a most disastrous financial operation.

FAILURE OF INOCULATION AS A PRIVATE ENTERPRISE.

Soon after this company began business in Chicago it was announced that an experiment would be made at the Peoria distilleries to demonstrate conclusively the value of inoculation. This Department sent a representative there to observe and report upon the results. As this report differs somewhat from the statement made by the company which performed the inoculation, the latter is given. It is as follows:

> Much curiosity exists as to an experiment we made at the Peoria distilleries. The plain facts are these: We put in 30 single inoculated hogs; 15 of them died. We

also put 18 double inoculated hogs; none of them died. Two others got in with these by mistake which had not been inoculated; these 2 died. We did this to see what we had to do in order to meet the peculiar conditions of feeding and the sudden change of food to which hogs are subjected at such places. We found out what we have to do to be successful, and hence the experiment answered our purposes.

From this statement we learn that of the 30 hogs inoculated according to the method recommended for farmers, 15 head, or 50 per cent, died when exposed. The ones that were twice inoculated can not be taken into consideration, because it is almost universally admitted that two inoculations are impractical on account of the expense, the trouble, the time required, the added risk, and the loss of growth in the animals. It will also be seen from the experience at Davenport, Iowa, an account of which follows, that the information obtained by the Peoria experiment did not avail to prevent loss when the experiment was repeated on a larger scale.

It is not the purpose of this bulletin to go into an examination of the details of the experience of this company with inoculation as practiced on farms. The following extract from an editorial article in the Ohio Farmer, August 9, 1890, shows the financial result of its operations:

> Dr. Billings, in another column of this issue, announces that he has decided to withdraw all his advertisements in which he endeavors to bring the inoculation of swine before the farmers as a preventive of cholera, because his efforts have been a financial failure. But, to show his faith in the process, he intends to go to farms where swine-feeding is the leading interest, purchase the hogs outright, inoculate them, and feed them at his own expense. He says: "The Government swine plague has no terrors for us."

Further particulars of this new undertaking to demonstrate the value of inoculation and to reap the pecuniary rewards which would follow from a successful method of prevention are found in the following editorial note printed in the Farmers' Review, August 20, 1890:

> We understand that Dr. Billings and those interested with him in business have lately purchased 10 acres of land at Dubuque [Davenport?], Iowa, adjacent to the glucose works in that city. Suitable buildings for the feeding of thousands of hogs at one time are to be erected at once; pipes for carrying food from the works to the feeding troughs are to be laid in; a contract has been made for the supply of sufficent food to feed 40,000 hogs during the year. A trustworthy agent is at present busily engaged in buying and inoculating 4,000 hogs with which to commence business. From all this it becomes very apparent that inoculation as a preventive against hog cholera is not by any means defunct. While farmers have not taken a unanimous share in the benefits of the method offered them in their business, Dr. Billings proposes to reap a deserved reward by turning feeder and pocketing the profits that hogs rendered ironclad against disease must surely yield when cheaply fed.

The results of this experiment and also of other experiments in inoculation are set forth in the following communication from Mr. E. M. Crummer, of Belleville, Kans., who for business reasons made a thorough investigation of the whole subject:

> My recent investigations of the merit of inoculation was prompted solely by the desire on my part to learn the real merits of it, so as to be able to recommend it to my patrons if I found it really efficient. I took considerable pains to make inquiries of disinterested parties who had tried it, and while I found some who had implicit

faith in it, the majority pronounced it an utter failure. And in all cases where it seemed (to the parties) to afford immunity, they really had not exposed it to a practical test. I have read most everything I could get treating on inoculation pro and con, and while I learned or suspected that in the main it had failed with the farmers, still I had a genuine hope that it would yet turn out to be practical, and that the failures might be overcome by learning the practical conditions under which to operate. A recent article in a Western stock paper stated that Dr. Billings had established at Davenport, Iowa, near the glucose works, a plant for feeding hogs on a more extensive scale than was ever before attempted. The plant was to represent an investment of from $50,000 to $100,000, and have a feeding capacity of from 5,000 to 10,000 hogs at a time; also that inoculation was to be their only protection from disease.

The article went on to state that they had already 1,600 hogs under feed, and all were doing well, and they had not lost one from disease. This statement, emanating from a stock paper which had sent their representative there, who had spent a day at the plant, caused me to think that certainly no man would invest so much money in an unproved theory, and that after all there must be some protection in it if rightly administered. I left home some three weeks since, and made a thorough investigation, to my full satisfaction. I was fully convinced of the utter failure of inoculation as at present administered, and was disappointed, as a matter of course. I found at Davenport a very extensive plant, designed for feeding the glucose refuse. Everything was pretty much as represented in the article referred to, except the immunity from cholera enjoyed from the use of inoculation. At the time I was there Mr. Billings was absent, but through the courtesy of the foreman in charge I was admitted and shown through the plant, with the exception of the quarantine department. The hogs on hand—what were left, and they were only a handful of the original number—were all down with the cholera. All the rest had already been inoculated before arriving at the plant, or after getting them there.

Instead of there being no losses from disease in the plant, they had kept right on dying until the remnants of the herd, most of which would survive the disease, were in the same condition as any other cholera herd, affected more or less with blood poisoning, etc. The only hogs on hand free from disease were a couple of carloads in the quarantine department that had not yet been inoculated, and since their arrival had been protected by disinfectants. The whole scheme of demonstrating the utility of inoculation is an abject failure. These hogs had been bought up by one of Mr. Billings's inoculators out in western Kansas. Most of them were inoculated where received, at the shipping stations, and several hundred died from the effect of cholera developed by inoculation at the places where bought, before shipping them into the plant. As you are not in so good a position to learn the inside facts, I have been thus frank and plain with you about it. The foreman and another gentleman who had helped through all the inoculations told me frankly that they had no confidence in inoculation, and advised me not to recommend it to my patrons. There is a Mr. Walker in Surprise, Nebr., who has had perfect success with inoculation, and who is going to do the inoculation of all the hogs hereafter at the plant. He was also going to ship in 200 of his own hogs that had been inoculated.

Mr. Henderson, at Junction City, Kans., whom I visited, and whom Dr. Billings quotes extensively, made no practical and conclusive test of it at all. He first inoculated a drove of hogs that were recovering from cholera. Afterwards inoculated pigs once or twice. These pigs failed to come down with cholera where the ground had been infected months before, which proves nothing. He made no actual heroic tests. The most practical test I learned of was made at Kearney, Nebr. Sixteen pigs, all healthy and free from disease, were inoculated, belonging to eight different farmers. Prof. B. sent out one of his men, Mr. Bassett, to do the inoculating and see that it was right. They recovered from the inoculation, were put in with sick hogs, and every one of them died. Then it was claimed that the virus was too weak. It seems

> that the whole trouble is in not being able to adapt the strength of the virus to the condition of each individual hog or pig.
>
> On the whole, I must say I feel like complimenting you on your good judgment and that of your associates in going slow in this matter, and not indorsing inoculation by Dr. Billings's process until you had first seen it thoroughly demonstrated. I am confident that a few words of indorsement from you would have resulted in introducing cholera where it had never been before, and in great losses to stock-growers.

This same correspondent wrote as follows nearly a year later:

> At the time I wrote you last winter or spring, I had returned from Davenport, Iowa, and was expecting a report from the foreman of the feeding plant on the results of the inoculation of the Wisconsin hogs which were then in the quarantine department, and which were to be inoculated by Mr. Walker, I think, of Surprise, Nebr. Well, I waited several weeks, and wrote to the foreman again. He then wrote me that the Wisconsin hogs "have got the cholera very bad now. When I see a success of inoculation I will write you." He never wrote me afterwards, although I wrote him another letter in order to get a more definite report.

After this last failure to make a success of inoculation as a private enterprise, Billings withdrew from the company and again accepted a position as investigator in the Nebraska Experiment Station. The attempt to prevent hog cholera by inoculation at the Davenport feeding establishment was abandoned. Inoculation was, however, still asserted to be a great success; an effort was made to introduce it extensively in the State of Nebraska, and this Department was repeatedly and most urgently pressed to make an investigation and satisfy itself that the claims of its advocates were not exaggerated.

AN EXPERIMENTAL TEST OF INOCULATION.

During the summer of 1891 there was an outbreak of swine disease in La Salle County, Ill. The farmers appealed to Secretary Rusk for relief, and, on their urgent request, Dr. E. C. Schroeder, of the Bureau of Animal Industry, was delegated to make investigations and to give such advice and assistance as were needed. An appeal was also made to F. S. Billings, of the Nebraska Experiment Station, and one of the farmers, Mr. Cadwell, had been to the laboratory of that station, where he spent some days under instruction, and returned home with the report that he had Billings' assurance that he could make the inoculations as well as any one.

On November 7, Dr. Billings gave a free lecture to the farmers at Ottawa on the subject of inoculation. The lecturer killed a diseased pig in the lecture room, and showed the farmers how to dissect it and how to make a culture of the germs for inoculating purposes, according to his method. He made such a culture, which was retained by Mr. Cadwell, already referred to as having been instructed at the Nebraska laboratory. He distinctly stated that the virus he then prepared was all right, and that it might be saved and used to inoculate hogs.

At the conclusion of this lecture, the Chief of the Bureau of Animal Industry being present, was called upon and made a short address, in which he explained that the Billings method of inoculation was practically identical with that used by the Bureau of Animal Industry in the spring of 1886, but which was found not to afford sufficient protection and to have other disadvantages which made it unsatisfactory for general adoption. He stated that it was the same as that used in Nebraska in 1888, when 400 hogs were lost out of 1,000 inoculated, and at Peoria in 1889, where 50 per cent. of the hogs inoculated died from cholera, and at Davenport, Iowa, in 1890, where the practice was attempted on a much larger scale and failed disastrously. He did not oppose inoculation, but pointed out the disadvantages and dangers connected with it which farmers should understand before they adopted it. In conclusion, he proposed to make an experiment in order to demonstrate to the satisfaction of all whether the Billings inoculation had any better effect in preventing the disease than that used by the Bureau, and to indicate whether either were of practical value as a preventive measure.

The plan he proposed was to purchase 99 healthy hogs, 33 of which should be inoculated by Billings, 33 by himself, and 33 to be left without inoculation; the entire 99 to be exposed to disease after a period of thirty days had elapsed, and the whole experiment to be under the supervision of a committee of the farmers themselves, who would report the results.

Dr. Billings promptly declined to have anything to do with such an experiment. The farmers, however, were much interested in the proposition and decided to carry it through, agreeing that Mr. Cadwell should make the inoculations on one-third of the hogs with the virus prepared during the lecture. At a meeting held in the evening the farmers decided that 20 hogs in each lot, 60 in all, would be sufficient for the experiment, and appointed a committee of five to superintend it. During the deliberations on the details, Billings affected a studied indifference, turning his back on those present and avoiding any participation in the discussion beyond a few remarks to the effect that he did not care what experiments were made in Illinois, he should continue his inoculations in Nebraska.

The hogs were purchased and ready for inoculation Saturday, November 21. The committee, the representatives of the Bureau of Animal Industry, and Mr. Cadwell were on hand, when the latter stated that Billings had written to him saying that he did not have confidence in the virus prepared by himself at the lecture and that he would send some virus, which he knew to be all right, from Chicago. This virus, however, he had failed to send and neither letters nor telegrams had brought any response from him. It was then agreed that Mr. Cadwell should go to Chicago in person to get the virus. This he did, expecting to be back and ready to make the inoculations on Monday, the 23d. Monday came, and all parties again met at the farm where the hogs were kept. Mr. Cadwell now reported that Billings declined to furnish him with any virus, but told him that the proper way was for him to make it at Ottawa. Inasmuch as Billings had frequently asserted and repeated his assertion at the lecture referred to, that he could teach any farmer in a very short time how to prepare the virus himself and how to inoculate, and inasmuch as Mr. Cadwell had received his instructions personally and had, furthermore, received assurance that he was competent to do both, it was agreed that the experiment should be carried out, the virus prepared by Mr. Cadwell being used upon one lot, that provided by the Bureau upon another, the third to be left uninoculated. And on the 28th of November these inoculations were so performed.

In a letter published in the Omaha Bee, Dr. Billings said:

> The reason I would not send virus from here was simply this: I am instructing farmers how to make their own, and am succeeding, and do it safely, for if inoculation is ever to become practical it must be a simple and cheap method.

In other words he asserts that the success of inoculation depends upon farmers being able to do it safely themselves, and, of course, if they are not successful in doing it themselves, then inoculation must, in his opinion, be a failure.

There has been a great interest manifested by the swine growers of all parts of the country in the results of this experiment, because it has been the first test under the direction of farmers that has been made with the necessary precautions to secure exact and reliable evidence on this subject. In this case great care was observed in arranging the details of the test, in selecting proper animals which had not been previously exposed to the disease, in locating the lots where the animals were to be kept, and in avoiding everything which would have a tendency to lessen the value of the experiment as a practical illustration of the results which may be expected to follow inoculation when performed according to the methods which have been most highly recommended.

The following is the report of the committee having the experiment in charge:

A proposition to test Dr. Billings' alleged discoveries in preventive inoculation for hog cholera, and the value of inoculation in general for this disease.

Sixty hogs, from four to six months old, shall be purchased and divided into three (3) lots, each hog to be marked with a numbered hog label in the ear; Mr. Cadwell to inoculate twenty (20) of these by his method; the Bureau of Animal Industry to inoculate twenty (20) of these by its method; to be inoculated once by each. The remaining animals to be kept separated from the inoculated animals, without inoculation. Immediately after the inoculation the two inoculated lots shall be turned together, and they shall not again be separated except by consent of both parties to the experiment. The farmers now present will select the farm upon which to keep the animals, and designate five (5) unbiased farmers who shall have charge of them, and who shall, at the end of the experiment, make a written statement as to what was done and what were the final results. Both parties shall be consulted as to the management of the animals, and particularly as to any changes in location, in feed, or in the care of the animals, and the report of the committee shall be confined to statements of facts; but the committee of farmers shall have the right to decide upon any disputed points in regard to these matters. One-half of the expenses for purchasing and keeping the hogs shall be paid by the farmers, and one-half shall be paid by Dr. Salmon. Inoculated and check hogs shall be turned together after thirty days, if possible on a farm where cholera exists.

The following committee was appointed:

Charles Eaton (chairman), Vermillionville, Ill.
A. E. Brunson, Northville, Ill.
W. H. Watts, Ottawa, Ill.
Harry Rockwood (secretary), Ottawa, Ill.
M. C. Hodgson, Ottawa, Ill.

The above proposition to test the value of inoculation as a preventive of hog cholera having been accepted, the farm of Charles L. Eaton, at Deer Park, La Salle County, Ill., was selected.

Fifty-five pigs were bought in localities free from hog cholera, and divided and inoculated as directed. The inoculations were made November 28, 1891. The inoculated hogs were kept in a 4-acre field, and the uninoculated hogs in a field, the area of which is about three-fourths of an acre. One corner of the field in which the uninoculated hogs were kept was separated only 20 feet from the field in which the inoculated hogs were confined. The water for the hogs flowed from the end of a tile draining an adjoining field in which no hogs had been kept. This tile opened in the lower corner of the field in which the uninoculated hogs were kept, and then passed into an open ditch which flowed in a curve to the lower end of the field in which the inoculated hogs were confined. The hogs were fed corn in the ear, and also received some ashes and salt. No change of consequence was noticed during the first nine days after inoculation.

December 7 two hogs were showing symptoms of disease, and December 10 the first pig died. This death was followed by others, until now only nineteen hogs remain. The dates upon which the hogs died are given below, together with the method by which they were inoculated, or with the name "check," signifying that they were not inoculated. The dates are as follows:

Died December 10	1 hog, Cadwell.
Died December 12	1 hog, Cadwell.
Died December 13	2 hogs, Cadwell.
Died December 18	1 hog, Cadwell.
Died December 20	1 hog, Cadwell.
Died December 21	1 hog, Bureau.
Died December 24	1 hog, Cadwell.
Died December 25	1 hog, Cadwell.
Died December 26	1 hog, Cadwell.
Died December 26	1 hog, check.

December 29.—At this point in the experiment, the thirty days having expired, the time during which the hogs should be separated, the checks and inoculated animals were turned together.

Died December 31	1 hog, Bureau.
Died December 31	1 hog, Cadwell.
Died January 1, 1892	1 hog, Bureau.
Died January 2	1 hog, Bureau.
Died January 3	1 hog, Bureau.
Died January 4	2 hogs, checks.
Died January 6	2 hogs, checks.
Died January 7	1 hog, check.
Died January 8	1 hog, check.
Died January 10	1 hog, Cadwell.

Died January 10	1 hog, check.
Died January 11	1 hog, check.
Died January 12 (missing—supposed to be dead)	1 hog, Bureau.
Died January 13	3 hogs, checks.
Died January 17	1 hog, Cadwell.
Died January 17	1 hog, check.
Died January 19	2 hogs, Bureau.
Died January 21	1 hog, check.
Died January 22	1 hog, Bureau.
Died February 5	1 hog, Bureau.

The condition of the remaining hogs is good, with the exception of three animals, and they will probably make a good recovery.

Charles L. Eaton.
H. E. Rockwood.
A. E. Brunson.
William H. Watts.
M. C. Hodgson.

It should be noticed that the first hogs to show sickness were those inoculated by Mr. Cadwell, and that this sickness appeared in nine days, or about the usual time which elapses between exposure and the appearance of disease. This indicates that the disease was caused by Cadwell's inoculation. Fourteen more days passed, during which 6 Cadwell hogs died before the first one of the Bureau hogs died. This indicates very clearly that the Bureau hogs contracted the disease from exposure to the Cadwell hogs. There are here two facts plainly brought out, viz: (1) the Billings method of inoculation may cause an outbreak of the disease it is designed to prevent; (2) the disease thus caused is communicated to other animals in the same manner that ordinary outbreaks of the disease are communicated.

The uninoculated hogs were turned with the inoculated ones on December 29. The object was, no doubt, to determine how many of these would die when exposed to this outbreak, and compare this number with that of the inoculated hogs which died. The final result of the experiment is that 14 of the 19 hogs not inoculated died; 12 of the 18 hogs inoculated by the Billings method died, and 10 of the 18 hogs inoculated by the Bureau died. The variation in the figures may be accidental, or it may show a slight degree of immunity conferred by the inoculation, particularly with the hogs inoculated by the Bureau, as one more of the Cadwell hogs and two checks were very sick, while all of those remaining in the Bureau lot are in good health. Practically, it must be admitted, there was no great difference in the effect of the exposure on the three bunches of hogs.

In order to explain the production of the disease by Cadwell's inoculation it has been stated by Dr. Billings and by editorials in certain papers that Mr. Cadwell had written a letter in which he asserted that "after Dr. Billings had refused to supply him with virus he was unable to secure a hog suffering from a mild attack of cholera. He could only get virus from a malignant form of disease, so he told the committee in charge that he was not satisfied; but they told him to go ahead, and he did so, with the fatal results stated in the dispatch." (Farmers' Review, December 23, 1891; also Nebraska State Journal, December 27, 1891, and January 22 and 29, 1892.) The Department has investigated this statement, and is satisfied that it is not correct.

When it became apparent that Dr. Billings was endeavoring to delay this test and avoid responsibility for the results, Dr. Schroeder, who represented the Bureau, was instructed not to go on with the experiment if Mr. Cadwell objected to any of the arrangements. Accordingly, before beginning the inoculations, Dr. Schroeder asked Mr. Cadwell if he was fully prepared and satisfied to go ahead, and whether he was perfectly satisfied with his virus. Both of these questions he answered in the affirmative. The following statement, signed by every member of the committee, confirms this statement, and shows that Mr. Cadwell, so far from being directed to use the virus against his wishes, acted strictly in accordance with his own judgment:

> We, the committee of farmers appointed to superintend the experiment of inoculating hogs at the farm of Charles L. Eaton, in Deer Park Township, La Salle County, Ill., by Dr. Schroeder, representing the Bureau of Animal Industry of the Department of Agriculture, at Washington, D. C., and Mr. George C. Cadwell, representing the so-called Billings method of inoculation, do hereby state, in regard to the report that we directed Mr. Cadwell to proceed with the inoculation on November 28, 1891, against his judgment, that we did not direct Mr. Cadwell to proceed with the inoculation on that date, but that he used his own judgment in the matter.
>
> Dated at Ottawa, this 1st day of February, 1892.
>
> CHARLES L. EATON.
> H. E. ROCKWOOD.
> A. E. BRUNSON.
> M. C. HODGSON.
> WILLIAM H. WATTS.

The facts appear to be that Mr. Cadwell had three flasks of virus, obtained from different sources, and he tried to get the committee to take the responsibility of saying which flask should be selected. This the committee very properly declined to do, since Cadwell had been instructed by Dr. Billings and represented him in the experiment. As a matter of fact, Cadwell made use of two of his flasks, inoculating half of his lot of hogs from one and the remainder from the other. The disease was caused by the virus from both sources.

The objection urged against this virus by Dr. Billings is that it was obtained from an outbreak where more than 50 per cent of the animals died. (Nebraska State Journal, January 29, 1892.) If this is to be the criterion in selecting the virus, it is obvious that no one can be certain as to whether or not he is using a proper virus. The virus must be obtained while the disease is in progress, whereas we can only know how many die from any given outbreak after the disease has ceased its ravages.

One flask of the virus used by Cadwell was obtained from the farm of Henry Richards, where 91 per cent of the animals died. Of the hogs inoculated with this virus 88 per cent died. The other flask was obtained from the farm of Nicholas Shawback. There were in this herd 146 hogs, of which 50 died, and 1 was killed by Cadwell to obtain virus. Eighty-three from this farm were sold apparently healthy, and 12 remained in good health at the time inquiry was made, about February 15. As a matter of fact, therefore, but 34 per cent of this herd died. Of the hogs inoculated with this virus 4 out of 9 died, or 44 per cent. That is, in the latter case, the virus was more fatal in the inoculated animals than in the herd from which it was obtained, while in the former case there was practically no difference.

The first hog to die was one inoculated with the Richards virus. Two days later 1 inoculated with the Shawback virus died. The day following this 1 died inoculated with the Richards virus and 1 with the Shawback. There can, consequently, be no doubt that the virus from both places produced fatal results.

After these facts were given to the press Mr. Cadwell wrote a letter of explanation, in which he stated: "I was satisfied in my own mind that the virus was not what I wanted. It did not work as I would like to have it." Mr. Eaton, the chairman of the committee, also stated that "Mr. Cadwell did say that he was not quite satisfied with the way it (the virus) had worked, but nothing said about the kind of an outbreak."

It would appear from these statements that the first objection raised to the virus by Dr. Billings had not been made by Mr. Cadwell. The facts given above show that under any circumstances this objection would not be valid, since one of the outbreaks from which the virus was taken corresponded with the instructions publicly issued from the Nebraska Experiment Station. There can be no question that this virus produced fatal results, as well as that from the more severe outbreak.

The question now arises, how much consideration should be given to Mr. Cadwell's statement that the virus "did not work as he would like to have it?" By this he undoubtedly meant that the appearance of the beef broth after the germs had multiplied in it was not exactly what he thought it should be. But why should he object to a culture because of its appearance? Nothing is said by Dr. Billings, in his instructions to farmers on inoculation, as to the rejection of cultures on account of their appearance. The essentials are there said to be that the virus shall be obtained from an outbreak of disease in which less than 50 per cent of the animals die, and from an animal in the first stages of the disease. He has expressly stated that such cultures are not expected to be pure, but that this makes no practical difference. This being the case, the appearance of the culture must necessarily vary according as it is contaminated with one or another of the atmospheric germs. Every one who has studied the question from a bacteriological standpoint knows that pure cultures of the germs of hog cholera will also differ in appearance when obtained from different outbreaks. This objection to the virus consequently has no bearing upon the results of the experiment. No one can tell from the appearance of a culture what its effects will be when hogs are inoculated with it.

The truth is, the advocates of inoculation were opposed to making a public and carefully guarded test. They could not decline the proposition to make such a test, however, because it was exactly what the people of that section unanimously demanded. They did delay the experiment on one pretext or another as long as possible. The date of inoculation was twice postponed, and even then there was this pretense of something being wrong with the virus, although the directions for preparing it had been scrupulously followed. It may be safely said that more care was exercised in selecting this virus than is usually given to the selection of virus for farmers' use. Three weeks' time in a section of the country where the disease is thoroughly disseminated surely should be sufficient to obtain material for inoculation, if the method is a practical one.

As an illustration of the difficulty of obtaining proper virus by this method, and of the dangers attending inoculation, it may be added that according to Dr. Schroeder's reports Mr. Cadwell inoculated 4 hogs by the Billings method previous to the beginning of the test experiment. Of these 2 died. Shortly after the experimental hogs were inoculated, Cadwell inoculated 5 hogs by the Billings method. Of these 3 died. He also inoculated 14 hogs and pigs by the same method on the farm of James Mitchell, near Utica, Ill. No trouble was noticed among these until four or five weeks after inoculation, when the disease broke out, and 10 animals, or 71 per cent, died.

It may also be stated in this connection that early in October, 1891, Mr. James Richey, of Tonica, La Salle County, Ill., obtained virus from the Chicago establishment organized by Dr. Billings, and at that time conducted by his former associate. Mr. Richey at once inoculated his herd of 90 animals, which were, in the words of the owner, "a first-class lot of young, healthy hogs." Nine days after the inoculation they commenced to die, and at the time of Dr. Schroeder's visit but 2 remained alive. The loss in this case was over 97 per cent.

This was the experience with the Billings method of inoculation in La Salle County, Ill., while Dr. Schroeder was stationed in that locality.

FAILURE OF INOCULATION IN NEBRASKA DURING 1891.

Under date of January 6, 1892, Dr. Billings addressed a letter to the Omaha Bee, in which he endeavored to explain the communication of disease by the inoculations made in accordance with his method at Ottawa, Ill. The following extract from his letter is of interest in this connection:

> I have inoculated some 50,000 hogs, and never in a single instance that I know of has such an accident occurred through inoculated hogs as at Ottawa, and there have

> been very few cases in which inoculation has not protected. True, I failed completely in protecting hogs that were fed on glucose refuse, but that was due to the glucose and not the inoculation. Hogs fed on distillery slops can be protected by inoculation. Every one who is acquainted with the true facts knows that those herds reported as killed at Surprise, Nebr., in 1888, were all diseased at the time they were inoculated. This year over 3,000 have been inoculated in Nebraska, and to-day I sent out virus for 1,900 more, but with some regrets, as I fear for its injury and the possibility of its being frozen. Of the 3,000 I do not know of one being injured by inoculation, yet one such case in sucking pigs is reported, and one failure in the same herd; the pigs I doubt, as five other lots of pigs were inoculated at the same time with the same virus, and they all lived; the failure I know the cause of, and have learned to avoid it in the future.

In spite of this very positive statement, the Department is in receipt of information from three different correspondents of undoubted reliability to the effect that on the 12th of August, 1891, 48 head of swine were inoculated on the State farm under the direction of Dr. Billings, and four of the herd were not inoculated. August 30, 4 pigs were dead, and 2 others very sick were taken to the laboratory for examination. Within thirty days after inoculation 26 died, and before the outbreak set up by the inoculation ceased its ravages 41 of the 52 hogs on the farm died. These facts were certainly known to Dr. Billings at the time the letter quoted from above was written.

With Western Resources for February 10, 1892, was included a supplement giving a statement by Dr. Billings of the inoculations made in Nebraska from August 18, 1891, to January 1, 1892. Why the inoculation on the State farm of August 12 was not included was not stated. In this statement were given more or less complete returns from forty-four herds inoculated. These herds contained 2,952 animals. Among these herds—in a column headed "Died from cholera after thirty days after inoculation"—there is one of 50 which lost 2; one of 163 which lost 2; one of 73 which lost 30; one of 89 which lost 40. These commenced to die three weeks after inoculation. Another herd of 31 lost 2; a herd of 279 lost 38; a herd of 108 lost 77; a herd of 24 lost 7; making in these herds a loss of 198. In addition to this there were eight herds in which losses occurred where it is stated that the herds were infected before inoculation. The evidence of their infection before the operation was performed is not given except in one case. With regard to this it is stated that only those were lost which were sick at the time. In regard to one of the herds it is stated: "I inoculated sows and pigs at the same time. The pigs died; all the old hogs lived."

In another case it is stated: "Sick at the time of inoculation, and lost 60 shotes, but none of the old ones." In regard to another herd: "Hogs sick at the time of inoculation. Lost 15 head." In another case: "Sick at the time of inoculation. My loss has been less than any of my neighbors." In another case: "No fair test. My hogs were sick when inoculated." In still another case: "Sick at time of inoculation; visibly so; 13 not sick; these 13 never got sick."

These explanations are given so that the reader can judge for himself as to whether in any of these cases the disease was caused by the inoculation.

The Department has received the following statements from parties who had hogs inoculated in Nebraska during the period under consideration:

W. Rotton, Unadilla, Nebr.:

I had 51 hogs inoculated. I have not lost any with cholera. I have not much faith in it, as I sold 8 shotes to a neighbor that had cholera some time before, and he lost 2 with the disease. They all took it, but all the others got over it, and are doing well.

Henry A. Dan, Boelus, Nebr.:

I do not think inoculation is a preventive. I inoculated on the 1st day of November 49 hogs, and from that time on my hogs have not done well, and the latter part of January the cholera broke out in my herd, and I have lost 10 up to this date, April 13. They have all been sick, and the pigs that were born came dead, or if alive they did not live twenty-four hours.

D. E. Palmblade, Axtell, Nebr.:

I had 72 hogs inoculated. Out of the 72 I sold the old ones, and out of the 55 young ones remaining, I lost about 17. None of them died from the inoculation, and they did very well before they became sick.

S. M. Geyer, Seward, Nebr.:

I inoculated 30 head in 1891 with virus prepared by Dr. Billings. It failed to produce any effect at all. I have not lost any since. As to my opinion of inoculation, I think it is more apt to spread the disease than to prevent it.

Hugh McLaughlin, Lincoln, Nebr.:

I inoculated about 50 hogs last fall, of which 20 died after inoculation. The others lived, and did well. They were all together at the time. I have not seen any sick since.

W. C. Dieterichs, Rockville, Nebr:

I had about 40 head of shotes inoculated last fall with virus and instruments sent to me by Dr. Billings, of Lincoln, this State. Two little pigs died soon after being inoculated. Do not know if inoculation was the cause. None died of the cholera except one, and that one got amongst a neighbor's hogs and staid several days amongst them. These hogs of my neighbor's had the cholera very bad at the time, although they had been inoculated on the same day mine were. My hogs did not thrive well after being inoculated, and always looked rough and not thrifty, although they had plenty to eat and were running at large. I do not think now that inoculation is a preventive for hog cholera. Perhaps the virus has something to do with it. My neighbor and I inoculated the same day. The virus I used was in another bottle than his. He lost 5 or 6 hogs, and I lost 1, but could not positively say it died of cholera as it died at the neighbor's. I do not think I shall want to inoculate again for a while.

A. B. Wright, Diller, Nebr.:

I inoculated 75 head of swine last fall, of different ages. The large hogs were damaged. Some of them lost in weight nearly 100 pounds. The shotes from six to eight months old I could see no difference in. I inoculated 19 sucking pigs, every one of which died. There has been no cholera in the neighborhood since I inoculated. My opinion is that inoculation is of little or no benefit.

John Campbell, Nebraska City, Nebr.:

On September 18, 1891, I inoculated 63 shotes about five months' old, and 22 old hogs, with virus received from Prof. Billings, of Lincoln, Nebr. In about ten or twelve days I lost 1 shote, and a good many of the shotes were sick. In about three or four weeks I had lost 59 of the shotes, leaving me 4. The shotes and old hogs had been in separate lots, not adjoining, but after inoculating, which was all done at the same time, I moved all the old hogs farther away from the others, with the exception of 1 lame one, and it died in about 30 days after inoculation, but the other old hogs have never had the cholera. I have not much faith in inoculation.

If we deduct from the total number inoculated, as given by Dr. Billings's statement (2,952), the number contained in the herds that were said to be diseased when inoculated (394), we have remaining 2,558 as the number inoculated which had not previously been exposed. Among these it is admitted that the loss from inoculation and exposure amounted to 198, or 7¾ per cent. This is nearly twice the average loss from all diseases of swine in the State of Nebraska for the year 1891, which is given as 4 per cent by the statistical division of his Department. If we correct this statement and make it accord with the letters received by the Department from the owners of the inoculated herds, which letters are given in this bulletin we must add the herd of John Campbell, which evidently was not infected before inoculation, but which plainly contracted the disease from the operation. We should also add to the losses the 2 belonging to W. Rotton, which died from exposure to cholera, the 10 belonging to Henry Dan, which probably contracted the disease from the inoculation, and the 3 belonging to W. E. Dieterichs. This would give a total of 2,643 healthy hogs inoculated and a loss of 273, or more than 10 per cent. This loss is two and a half times the average loss of the State for the year from all diseases.

There are a considerable number of owners of inoculated herds in the list from whom the Department has received no replies, and it is therefore probable that full returns would considerably increase the percentage of loss as given above. It will also be noticed that no account has been made of the 48 head inoculated on the State farm, of which 79 per cent died from the inoculation. If inoculation on the State farm, where all the conditions can be controlled and where the hogs are under the personal supervision of the operator, is followed by such disastrous results, it certainly can not be safe on farms throughout the country where such advantages are impossible.

THE FINANCIAL ASPECT OF INOCULATION.

It is very apparent, from the facts presented in this bulletin, that inoculation is a very dangerous operation, and that the protection from it is, at best, uncertain, and in many cases entirely wanting. With these incontestable conclusions in mind, we will give some figures on the losses from swine diseases and the cost of inoculation. Two years ago the following statement was made:

According to the estimates of the statistical division there are about 50,300,000 hogs in the United States. The inoculation of these at 50 cents per head would cost $25,150,000. The total loss from disease during the year 1888 was 3,105,000 hogs, at an average value of $5.79 each. This would make the total loss of swine from all diseases $17,980,000.

In order to estimate the loss from hog cholera we must deduct from this sum the losses from ordinary diseases, such as animal parasites, exposure, overcrowding, and improper feeding, which are always acting and do not produce epizoötic diseases. These losses were estimated by the statistician of the Department in 1886 to be about 4 per cent of the total number of hogs, but as this may be considered rather a large estimate we will, in our calculation, take 3 per cent as the average loss from such causes. This would amount in 1888 to 1,509,000 animals, valued at $8,737,000, and deducting this from the total loss of swine we have remaining $9,243,000 as the losses from epizoötic swine diseases. In the present condition of our knowledge we must admit that there are at least two entirely distinct epizoötic diseases of hogs, which have been referred to in the reports of this Bureau as hog cholera and swine plague. The exact proportion of the loss caused by each of these diseases is at present unknown, but if we admit for the purposes of this calculation that but one-third of the loss is caused by swine plague we have remaining a loss of but $6,163,000 for the year 1888, which can be attributed to hog cholera. To prevent this disease by inoculation, as we have just seen, requires the expenditure in cash of $25,150,000, or more than four times the amount of the actual losses. In addition to this expenditure there should be counted the time required of the farmer in handling the hogs at the time of the operation and in giving them such precautionary care and in practicing such disinfection as is required to make this operation at all successful.

We should reach the same conclusion if, instead of estimating the loss and expense for the whole of the United States, we should take a single hog-raising State, as for example, the State of Illinois. According to the statistician's estimate there are 5,275,000 hogs in Illinois, and to protect these by inoculation would cost $2,637,000. In the year 1888 the total losses of hogs in that State from all diseases was about 316,500, with an average value of $7.45 each, which would make the loss for that year $2,359,925. Deduct a loss of 3 per cent of all the hogs in the State as caused by ordinary diseases, and we find that this would amount to 158,250 hogs, worth $1,178,962. Deducting the losses caused by ordinary diseases from the total losses from all diseases and we have $1,180,963 left to represent the loss from both hog cholera and swine plague. Take from this one-third, to represent the loss from swine plague, and we have remaining, as the loss from hog cholera, about the sum of $800,000. To prevent this loss by inoculation, as we have seen, would require $2,637,000, or more than three times the sum to be saved.

In the above calculations we were considering inoculation when practiced as a private enterprise, with a charge of 50 cents per head for the operation. It has since been proposed that the virus and instruments should be supplied by the State experiment stations and that the farmers should perform the operation themselves. This would no doubt reduce the cost of inoculation to 25 cents a head for the time and trouble involved in the operation, the expressage on the instruments and virus, and the precautions necessary to prevent the spread of the disease to other herds. To this we must now add the loss following the operation when performed on healthy herds. This we have just seen has been with 2,643 animals inoculated the last year, and with every precaution that could be adopted, over 10 per cent. If the hogs average $5 per head in value this would be an additional expense of 50 cents per head for each inoculated animal.

Some herds during the past year were badly stunted. In some cases animals not only stopped growing, but they lost 50 or 100 pounds in weight. Such losses are very serious and amount to much more than the cost of the operation, or even the value of the animals which die from it. The hog crop is practically an annual crop. In many cases hogs are sold at six to eight months of age. Now, it is very plain that to subject animals marketed at this age to an operation which stops the growth of all, or of a considerable proportion of them, for one or two months is to deprive the farmer of all chance of profit from this industry.

FARMERS' BULLETINS.

The bulletins of this series may be obtained by applying to the Secretary of Agriculture, Washington, D. C. The following have been previously issued:

Farmers' Bulletin No. 1. The What and Why of Agricultural Experiment Stations. (A brief explanation of the object, origin, and development of the stations, their work in Europe and in the United States, and the operations of the Office of Experiment Stations of the Department of Agriculture.) Prepared by the Office of Experiment Stations; pp. 16. Issued June, 1889.

Farmers' Bulletin No. 2. The Work of the Agricultural Experiment Stations; (Illustrations of Station Work in the following lines: better cows for the dairy; fibrin in milk; bacteria in milk, cream, and butter; silos and silage; alfalfa; and field experiments with fertilizers.) Prepared by the Office of Experiment Stations; pp. 16. Issued June, 1889.

Farmers' Bulletin No. 3. The Culture of the Sugar Beet. (Treats of the climatic conditions, soil, fertilizers, and cultivation required by the sugar beet, cost of growing, time to harvest, and method of soiling; describes briefly the process of beet-sugar manufacture, and gives statistics of sugar production and consumption.) By H. W. Wiley, chemist of the Department of Agriculture; pp. 24. Issued March, 1891.

Farmers' Bulletin No. 4. Fungous Diseases of the Grape and their Treatment. (Describes downy mildew, powdery mildew, black rot, and anthracnose of grapes, and gives instructions for their treatment and estimated cost of remedies.) By B. T. Galloway, Chief of the Division of Vegetable Pathology; pp. 12. Issued March, 1891.

Farmers' Bulletin No. 5. Treatment of Smuts of Oats and Wheat. (Describes the smuts of wheat, oats, and barley, the damage they cause, and the various methods of treatment which have been found useful for their prevention.) Prepared by the Division of Vegetable Pathology; pp. 8. Issued February, 1892.

Farmers' Bulletin No. 6. Tobacco: Instructions for its cultivation and curing. Prepared by John M. Estes, special agent; pp. 8. Issued February, 1892.

Farmers' Bulletin No. 7. Spraying Fruits for Insect Pests and Fungous Diseases, with a Special Consideration of the Subject in its Relation to the Public Health. Prepared by the Divisions of Entomology and Vegetable Pathology; pp. 20. Issued April, 1892.

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 9.

MILK FERMENTATIONS

AND

THEIR RELATIONS TO DAIRYING

PREPARED IN THE OFFICE OF EXPERIMENT STATIONS FROM
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., June 15, 1892.

Sir: A popular summary of Prof. H. W. Conn's review of the investigations on the fermentations of milk, which was originally issued as Experiment Station Bulletin No. 9 of this Office, is herewith transmitted for publication as a Farmers' Bulletin. The practical importance of the results of recent bacteriological investigations of milk and its products to an intelligent practice of improved methods of dairying, calls for the wide distribution of a condensed statement of the outcome of these researches among dairymen and farmers.

Respectfully,

A. W. Harris,
Director.

Hon. J. M. Rusk,
Secretary of Agriculture.

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MILK FERMENTATIONS AND THEIR RELATIONS TO DAIRYING.

In the following pages the word fermentation will be used in its broadest sense. It will include not only the fermentations produced by yeast and rennet, but also all of the numerous destructive changes to which milk is subject, and will cover, therefore, all of the changes which occur in milk, such as curdling, souring, and putrefaction.

COMPOSITION OF MILK.

It will be necessary at the outset to notice briefly the chemical composition of milk, since upon this are based all of its fermentative changes. While the composition of samples of milk obtained from different cows and produced under different conditions may show wide variation, a fair average composition may be given as follows: Water, 87 per cent, and solids, 13 per cent. The solids include fat, 3.6; casein, 3.3; albumen, 0.7; milk sugar, 4.7, and ash, 0.7 per cent. The casein and albumen are the materials containing nitrogen and are of special importance in cheese-making. In general the ash, sugar, and albumen are in solution, the casein in partial solution, and the fat in suspension, being mixed with the milk, but not dissolved in it. Milk when freshly drawn from the cow is a thin liquid, but after standing for a short time becomes slightly viscous or ropy through the formation in it of a small amount of fibrin.

Milk fat consists of a mixture of several fats. As its composition begins to undergo changes almost immediately after the milk is drawn, its exact condition at any moment is very uncertain. It is distributed throughout the milk in the form of minute globules varying in size. The belief that there is an albuminous membrane around the globules which keeps them from combining readily has been abandoned. The whiteness of milk has usually been attributed to the presence of these globules of fat, but is probably due in part to the phosphate of lime which milk contains.

In regard to the nature of the *casein* of milk there has been much discussion. In the first place, it seems certain that casein does not exist in milk in a state of complete solution, but rather in the form of finely divided particles. Probably some of it is in actual solution, while the greater part is in a state of suspension. When milk is filtered through porcelain a clear liquid called milk serum passes through the filter, the casein and fat being left behind. In this serum there is a certain amount of albumen and usually part of the casein also, which has been in solution in the milk; but the fact that most of the casein does not pass the filter shows that it is not in a state of complete solution. The relation of the soluble and insoluble portions of the casein is a matter of much importance in the study of milk fermentations. The coagulation of the casein, or curdling, as the process is commonly called, is readily effected by rennet and also by various chemicals, among which are lead acetate, sulphate of copper, alum, corrosive sublimate, tannic acid, sulphate of magnesium, and the mineral acids, but is not effected by boiling.

The *albumen* of milk is in complete solution and seems to differ only slightly from the serum albumen of the blood. Considering the intimate relation which the milk while in the mammary gland must have with the blood, or rather with the lymph, *i. e.*, the blood deprived of its red corpuscles, it is not surprising to find one of the constituents of milk so similar to this albumen of the blood. We may probably look upon it as derived directly from the albumen of the lymph. The presence of this serum albumen is perhaps an important factor in explaining the changes which take place in milk upon standing.

Milk sugar exists in milk in a state of complete solution. It may be obtained by evaporating and crystallizing whey.

The *ash* of milk contains potash, soda, lime, iron, and magnesia, in combination with muriatic, phosphoric, and sulphuric acids, and other constituents. These are all in solution except, perhaps, some of the lime compounds.

Besides the above-mentioned constituents, minute quantities of several other compounds are found in milk, but these have not yet entered into the study of milk fermentations and at present may be neglected. Milk is a very complex body, and a complete study of its fermentations would, of course, take into consideration all of its constituents. At present, however, our knowledge is confined to the study of the fermentations as affecting milk sugar and the casein, albumen, and fat of milk.

CAUSES OF FERMENTATION.

The organisms and substances concerned in the fermentation of milk may be divided into two distinct classes, namely, organized and unorganized ferments. The former include the minute living organisms (microörganisms), such as bacteria, yeasts, etc., which by their growth cause changes or fermentation.

The unorganized or chemical ferments, on the other hand, are substances devoid of life which are capable of causing certain chemical changes in other substances without themselves being changed. Rennet and pepsin are familiar examples of unorganized ferments.

Bacteria proper, which have most to do with milk and cream, are found in immense numbers everywhere, and play an important part in nature. They are all extremely minute. In shape they show three chief varieties, which may be compared, respectively, to a lead pencil (*bacillus*), a ball (*coccus*), and a corkscrew (*spirillum*). With the highest powers of the microscope they appear as scarcely more than simple dots and lines. They are to be classed with plants rather than animals, in spite of the fact that many of them are endowed with motion.

The isolation and cultivation of a single kind of bacteria is a matter requiring the greatest care. Although imperfectly studied as yet, many different forms are known which are distinguished by their habits of growth, the substances in which they thrive, and the changes which they produce in various substances as a result of their growth. Bacteria are cultivated in beef broth, gelatin, and other substances which, when used for these purposes, are called *cultures*. What is known as a *pure culture* contains only one kind of bacteria.

Yeasts are also plants of a low order, which grow very rapidly in certain substances and thus cause changes which are commonly called fermentations. The most common kind of yeast is that used in making beer and raising bread.

FERMENTATION OF MILK BY RENNET.

Rennet is a preparation usually made from the stomach of a calf, and has the power of coagulating the casein of milk in a very short time. This curdling of milk by rennet is the only form of fermentation of milk known which is produced by an unorganized ferment.

Many investigations have been made to determine how rennet acts on milk and causes it to curdle. The results are certainly not yet very conclusive nor very satisfactory, but the following general summary may serve to bring together the conclusions which are to be drawn from the facts thus far observed. Casein appears to be kept in partial solution by the alkaline condition of the milk, for it is easily separated from the solution by the presence of a small quantity of acid; but when thus separated it seems to be simply thrown from its solution without being altered in its nature, while the active principle of rennet has a very different effect upon it. Under the action of rennet the casein is chemically changed. It is broken up into two nitrogenous bodies (proteids), one of which is easily coagulated, while the other is coagulated only with great difficulty. The former is readily thrown from its solution by salts of calcium (lime), and since these are always present in the milk, the result of rennet action is always to throw down the curd. This portion of the original casein is then manufactured into cheese, while the other portion, being soluble, goes into the whey and is lost to the cheese-maker. The amount of protein thus lost may be still further increased through the action of bacteria, which have the power of making even curdled casein soluble, and this fact teaches the advisability of using rennet in a manner which will produce the coagulation as quickly as possible. The rapidity of the action will depend upon the relative amount of rennet and the temperature, and may be lessened by alkalies and increased by various salts. The active principle of rennet is a chemical ferment which is distinct from the other digestive ferments in the stomach juices. It seems to be somewhat widely distributed in nature among animals and plants, and it is a common product of bacteria growth. It is destroyed by a temperature of 158° F., and it acts best at about 95° F. It is undoubtedly to be regarded as one of the digestive ferments.

THE SOURING OF MILK.

The normal souring of milk has until quite recently been regarded as a characteristic of milk itself, unassisted by any outside influences. To-day, however, there is such a uniformity of results on the part of all experimenters that it is no longer possible to question the fact that the souring of milk is a fermentative process produced by organisms which get into the milk after the milking is done.

After much investigation bearing upon the subject had been carried on by Pasteur and others, Lister, about 1873, found in milk several forms of bacteria which at first he thought were all of one species, but afterwards found to belong to independent species. It appeared, moreover, that while there is one species of bacteria which produce the lactic acid accompanying the souring of milk, there are others which have different effects. The lactic organism, he determined, is common around the dairy, but not common elsewhere in nature, not even in the barn. He found that sterilized milk, if exposed to the air in different places, in his laboratory, in a barn, or in the open air, or if inoculated with water would ferment after a time, but would not sour; in fact, the souring of milk was found to be rare except in milk which had come directly from the dairy. This somewhat surprising observation has been confirmed, and hence the conclusion is forced upon us that the lactic organism is peculiar to the dairy, but is not especially abundant elsewhere in nature. Careful experimenters now have no difficulty in obtaining milk free from bacteria.

Later investigations have shown that there are several kinds of bacteria which may cause the souring of milk. It is doubtful, however, whether any two of the organisms of this class act on milk in precisely the same way. It is probable that the decomposition of milk may take place in a number of different ways. While we are certain that the fermentation of milk, commonly known as souring, is caused by bacteria, we have yet much to learn regarding the details of the process.

NUMBER OF BACTERIA IN MILK.

These organisms all get into the milk from external sources, such as the air, the hands of the milker, the hair or udder of the cow, and especially from the vessels into which the milk is drawn. It is plain that the number present in the milk will vary with the cleanliness used in the dairy and barn. If the udder of the cow be carefully cleaned and the milk be drawn into a glass tube which, by heating, has been made free from all living germs, and which can be closed so as to keep from the milk all unfiltered air, it is easy to get milk so free from bacteria that it will remain unaffected for two weeks, even though kept all the time in a warm oven.

The number of bacteria present in milk depends chiefly upon the length of time the milk has been standing and upon the temperature. Estimates based upon milk under different conditions have shown them to be almost innumerable. In one instance a specimen of milk which had been standing for four days in a cold place was found to contain about ten millions of bacteria per quart. The same milk was then allowed to stand in a warm room for seven hours, and during this time the bacteria increased a hundredfold. So far as the practical side of this discovery is concerned it only makes more evident the value of keeping milk as cool as possible from the very outset, if we wish to avoid the troublesome growth of bacteria. For a day or two the bacteria increase with great rapidity, then their multiplication is checked, and finally they entirely cease to grow. This can not, of course, be due to a lack of food, for there is plenty of food in the milk at all times. It is rather to be attributed to the accumulation of the products of their action. Those growths which produce an acid will soon be checked by this, for bacteria can not grow in an acid medium. The amount of acid, however, will vary, for some species of bacteria are very sensitive to acid, while others will endure a larger amount without injury.

RELATION OF ELECTRICITY TO THE SOURING OF MILK.

A consideration of the subject of the souring of milk would not be complete without reference to the effect of electricity. The popular belief that thunderstorms will sour milk is so widespread that it would seem as if there must be some foundation for it. It has been asserted by many that the ozone produced in the air by electricity causes the milk to become sour. In experiments in which electric sparks were discharged over the surface of the milk, however, little or no effect has been produced upon it. The conclusion is that electricity is not of itself capable of souring milk or even of materially hastening the process. Nor can the ozone developed during the thunderstorm be looked upon as of any great importance. It seems probable that the connection between the thunderstorm and the souring of the milk is one of a different character. Bacteria certainly grow most rapidly in the warm, sultry conditions which usually precede a thunderstorm, and it frequently happens that the thunderstorm and the souring occur together, not because the thunder has hastened the souring, but rather because the climatic conditions which have brought the storm have at the same time been such as to cause unusually rapid bacteria growth. Milk deprived of bacteria will certainly keep well during thunderstorms. Dairymen find no difficulty in keeping milk if it is cooled immediately after being drawn from the cow and is kept cool. Milk submerged in cool water is not affected by thunder. Dairymen find that during "dog-day" weather, even when there is no thunder, it is just as difficult to keep milk as it is during thunderstorms; and they also find that scrupulous cleanliness in regard to the milk vessels is the best possible remedy against souring during a thunderstorm. It is safe to conclude, therefore, that in all cases it is the bacteria which sour the milk, and if there seems to be a casual connection between the thunder and the souring it is an indirect one only. Climatic conditions have hastened bacteria growth and have also brought on the thunderstorm. The same conditions would affect the milk in exactly the same way, even though no thunderstorm were produced, and this effect, our dairymen tell us, is frequently observed during the warm, sultry autumn days.

OTHER FORMS OF FERMENTATION OF MILK.

Students have not recognized until in recent years that a great variety of fermentations may occur in milk. The reason for the tardiness of this discovery is easily seen. Under ordinary conditions milk always undergoes some sort of lactic fermentation (souring). Only under rare conditions is this absent. The production of lactic acid soon curdles the milk and immediately obscures all other forms of fermentation which have occurred during the process. The acid also stops the growth of all bacteria, so that no subsequent effect can be seen. Hence in normal milk clear evidence of fermentation of any other sort than souring is rarely noticed. But the study of bacteria from the time of the earlier investigations of Pasteur has shown the existence of a large number of species of organisms, and though for a time the fact was disputed, it soon became definitely demonstrated. It became evident, therefore, that with a variety in the species of organisms a variety in the fermentations of milk could be expected. Our knowledge of the newly discovered fermentations is by no means complete as yet. We are beginning to recognize that each species probably has its own distinct effect on milk, and the matter thus becomes very complex. Still we are already able to divide these many varieties of the fermentations of milk into classes, each characterized by a single general action, but comprising many varieties. The first class has been noticed, its general characteristic being the production of lactic acid. The second class is characterized by the production of an alkaline reaction instead of an acid.

ALKALINE FERMENTATION OF MILK.

The fermentation of milk is not always accompanied by the production of an acid. It has been ascertained that no lactic acid appears in spontaneously fermenting boiled milk. The milk may become coagulated into a soft, slimy mass, which usually possesses a bitter taste. The taste is never sour, and the milk, instead of having an acid reaction, is either alkaline or neutral. After a day or two the curd begins to dissolve into a somewhat clear liquid, and, if the action is allowed to continue long enough, may become completely dissolved into a semi-transparent liquid having no resemblance to milk. The chemical study of this liquid shows a variety of ingredients, among which are peptones, leucin, tyrosin, and ammonia. To the peptones the bitter taste may be at least partly attributed, and to the ammonia the alkaline reaction.

Many varieties of fermentation are accompanied by the alkaline reaction, but three distinct features of the general class may be conveniently selected for discussion. The formation of butyric acid, the formation of a bitter taste, and the curdling of the milk, with the subsequent dissolving of the curd, are all striking characters which may be considered separately.

BUTYRIC ACID.

As early as 1843 the formation of butyric acid in milk was observed, but it was not until 1861 that Pasteur associated this fermentation with a distinct organism. His cultures of it were not pure ones, however, and his results were not satisfactory to us of to-day. But the work was of the utmost value, since it was a departure in a new direction. Pasteur studied the organism enough to discover the very important fact that it grows best out of contact with air.

In 1880 Prazmowski made a careful study of the organism and named it *Bacillus butyricus*. The species described under this name grows rapidly in the absence of oxygen. Boiling will not kill the germs of this butyric organism, and hence milk after boiling will be pretty sure to undergo the butyric fermentation. Its growth in normal milk is not very great for the first few days, nor, indeed, until the milk sugar has been largely turned into lactic acid by the ordinary lactic organisms. The butyric species will certainly grow in sterilized milk, where there is no possibility of the production of lactic acid, but where the growth seems rather to be due to the presence of the oxygen dissolved in the milk.

After the work of Prazmowski others studied the butyric organisms, and their descriptions, which were found to differ considerably, caused much confusion. More recently other species have been found, and the butyric-acid class seems to be as large as the lactic-acid class of organisms. Some of the butyric organisms produce alkaline reactions, while others render the milk acid. In the ordinary handling of the milk this class of organisms is of little importance, but it has been supposed that they have an important effect upon the keeping properties of butter. Rancid butter contains considerable quantities of butyric acid, and the development of the rancidity is simultaneous with the appearance of the butyric acid. When it became known that many species of bacteria produce butyric acid and that there are many bacteria in butter, it was a natural inference that the rancidity is produced by them. But it now appears very doubtful whether bacteria have much to do with the change. Rancidity may be hastened by them, but will occur when they are entirely absent, and is probably of the nature of a direct chemical oxidation closely connected with the agency of sunlight.

BITTER MILK.

Out of the general confusion which has surrounded the subject of butyric fermentation have gradually crystallized some definite ideas in regard to the phenomenon known as bitter milk. The milk of old milch cows is said to have a tendency to be bitter, and various foods which the cow may eat are also thought to have the effect of producing bitter milk. Probably these and other causes may be occasionally at work, but in addition it is certain that microörganisms are frequently the cause of the trouble. At times it is associated with the production of butyric acid, and at other times it is produced by organisms which do not produce butyric acid, but in all cases the bitterness seems to be independent of the acid. Evidently there is quite a number of species which produce this effect. Three have been described with care, and several others incidentally noticed, but we have no means of knowing how numerous they are.

ALKALINE CURDLING OF MILK.

One of the common effects of the alkaline bacteria, though by no means a universal one, is the curdling of the milk. The alkaline reaction of the milk proves, of course, that the curdling can not be due to the formation of an acid as in the ordinary souring. From the investigations thus far made we are forced to the conclusion that certain species of bacteria give rise simultaneously to two distinct forms of fermentation in milk, one producing a rennet-like curdling and the other a digestion or dissolving of the casein. So far as is known to-day, the curdling power is always accompanied by a digesting power, but some instances are known in which bacteria have the digesting power without the curdling property.

The curdling of milk by these organisms is very similar to that produced by rennet. In the ordinary handling of milk the class of organisms included under the head of alkaline ferments is of little importance. They grow slowly and the lactic-acid-forming species usually get the start of them, producing their own marked effect on the milk, so that the action of the alkaline species is entirely obscured. Moreover the acid-forming species soon produce so much acid that the growth of all bacteria is checked, and thus the alkaline species have no chance to produce much effect on the milk. At the same time these species are of the greatest importance in dairy matters. In the first place many of them form resisting germs which will endure high temperature and render it very difficult to sterilize milk by heat. They are always present in milk which has been standing for a short time, and sometimes their abundance is great enough to produce noticeable effects. Everyone who has had an extended experience with milk has seen instances of milk curdling without the usual acid taste, and it is a familiar fact that curdled milk is by no means constant in character. There is the greatest variety in the stiffness of the curd, the amount of the whey, the taste, odor, etc., and all of these differences are due to varying numbers and species of bacteria other than the lactic-acid class.

Among the numerous species of bacteria affecting milk those producing the rennet-like curdling are abundant, and their share in the ordinary fermentations of milk is not a small one, especially in cool weather. In the keeping property of butter they doubtless play a part, though they are not the sole cause of rancidity. In the ripening of cream for churning their part is still greater, and in the ripening of cheese they are of the utmost importance. Undoubtedly we may trace many of the difficulties of the butter and cheese maker to bacteria of this class. A further knowledge of their action will be of great value to the dairy interest. We are as yet only on the threshold of the study of these organisms, for while the lactic-acid organisms have been quite carefully studied in past years the rennet-forming class has only recently come into notice.

BLUE MILK.

This fermentation, characterized by the deep blue color which has given it its name, occurs sometimes as an isolated trouble in individual dairies, and sometimes it has become so prevalent in certain localities as to be almost an epidemic. The explanation now given for blue milk is a double one. Ordinary milk contains some of the lactic-acid organisms, and these, acting in connection with another species of bacteria known as *Bacillus cyanogenus*, produce the brilliant blue color which characterizes this infection. When growing in ordinary milk the effect of this organism is very marked. For a few hours no change is noticed, but just about the time when the milk begins to become acid some intense blue patches make their appearance. The faster the acid forms the quicker the coagulation appears and the smaller are the blue patches, while if the acid is produced more slowly the blue patches are larger and of a better color.

Where the blue-milk organism comes from is unknown, nor have we any knowledge of the causes of the occasional epidemics of blue milk. There can be little doubt that the cause is always from some unknown source of filth. In some cases the trouble has been traced to a single cow in a large dairy, and has been easily stopped by isolating the individual found to be the cause, or by carefully washing the cow's teats with a little weak acetic acid solution. Blue milk is always an infection due to outside contamination, and its remedy is always to be found in care and cleanliness. It does not occur in the carefully kept dairy.

Blue milk appears to be harmless. It has been fed to animals, which eat it readily and without harm. Within a few years blue cheese has been brought to the attention of scientists, and has been attributed to the same organism which produces the trouble in milk.

ALCOHOLIC FERMENTATION OF MILK.

Milk does not readily undergo alcoholic fermentation. Koumiss, a beverage prepared from mares' milk from time immemorial by the nomadic tribes of Tartary, contains alcohol produced by alcoholic fermentation of the milk. Within the last few years this drink has become somewhat common as a beverage for invalids and for that purpose is prepared from cows' milk by adding a little sugar to induce alcoholic fermentation. Another alcoholic drink obtained from milk is the "kefir" of the Caucasus. In both of these beverages the alcoholic fermentations of milk are accompanied by various other fermentations. Within recent years it has been discovered that there are numerous organisms capable of producing an alcoholic fermentation of milk sugar when acting alone. Among these are at least two or three species of yeast. It appears that small amounts of alcohol are produced in some of the common forms of lactic fermentation, and finally we have found that almost any species of yeast can produce alcohol from milk if the process be first started by adding to the milk a little of the easily fermentable cane sugar. So well known is this alcoholic fermentation to-day that it has recently been suggested that the use of whey in the manufacture of alcohol on a large scale would be a profitable undertaking.

SLIMY FERMENTATION.

A slimy fermentation of milk is a somewhat common occurrence and occasionally produces great trouble in dairies. Slimy milk has an important bearing upon the manufacture of Edam cheese. Elsewhere, too, this fermentation is a troublesome one, since it destroys the milk for all ordinary uses. Such milk will furnish no cream. It can not be churned and is ruined for drinking purposes.

There have been the greatest variety of theories as to the cause of slimy milk. Diseases of the mammary gland, variations in the food of the cow, and differences in conditions surrounding the dairy have all come in for a share in the explanation. But the slimy fermentation of milk has been found to be connected with a large variety of organisms. Some of them give to the milk only a slight sliminess, while others render it tenacious almost beyond belief. One, described by Conn, renders the milk and other solutions so slimy that it can be drawn into threads 10 feet long, and so small as to be hardly visible. Some of the organisms render milk slimy in their early growth, others only after several days, and some do not render the fresh milk slimy at all, but first curdle it and then dissolve the curd into a slimy solution. So far as their chemical side is concerned, the fermentations are also widely different from each other, although not sufficient is known to enable us to classify them all at present.

MISCELLANEOUS FORMS OF FERMENTATION.

In addition to the above well-marked classes of fermentation there are various others not so well known or so carefully studied. Among them are some organisms that produce especially striking effects from the production of pigments. Blue milk has already been noticed, but several other pigment-forming species of bacteria cause milk to turn violet, yellow, green, or red.

Of other miscellaneous forms of fermentation, very little is known beyond the mere fact of their existence. The fact is that milk is an excellent medium for bacteria growth. It furnishes proper food for all of the bacteria connected with decomposition, and the various organisms of the air or the water may grow in it to almost any extent. The study of its fermentative changes resolves itself, therefore, into the study of fermentation in general. Fermentation, decomposition, putrefaction, etc., will all run into each other in the study of the changes occurring in milk, and it is impossible to draw any line separating them. For a complete knowledge of the fermentations of milk, we must wait until we understand thoroughly the process of fermentation and decomposition in general. At present this is an almost unknown field. We can pick out a few of the simpler, more striking types of fermentation and group them into classes as we have done, but we must leave for future study the miscellaneous forms of decomposition and fermentation whose existence we recognize, but of whose nature we are entirely ignorant.

PRACTICAL BEARING OF THE SUBJECT UPON DAIRYING.

After this review of the fermentations of milk, the question of their practical bearing forces itself upon our attention. It is becoming more and more evident every year that their bearing upon dairying is of the utmost importance. The practical application of our knowledge of the fermentations of milk will concern each of the three chief dairy products, milk, butter, and cheese.

HANDLING MILK.

To those dealing with milk itself in any form, the various fermentations are especially undesirable and are constant sources of trouble. Such persons want the milk pure and sweet, and any of the various forms of fermentation injure the milk for their purposes. Now, so far as these matters are concerned, our study of milk fermentation has taught us first of all *that all fermentations of milk, even the common souring, are due to the contamination of the milk with something from the exterior after it is drawn from the cow.* If they are thus all due to contamination from without, all that is needed to prevent them is to treat the milk in such a way that no such contamination is permitted. But simple as this is in theory our study has shown us that it is a matter of practical impossibility. The various organisms affecting milk are so numerous and so common everywhere that no practical method can be devised for keeping them out of the milk. The person who handles milk must therefore recognize their presence in the milk as inevitable, and he must simply turn his attention to means of reducing them to the smallest number and keeping their growth within the smallest possible compass. This has been shown to be accomplished best by two precautions, absolute cleanliness and low temperatures. The great source of these organisms is in the unclean vessels in which the milk is drawn and in the filth which surrounds the cow. By scrupulous cleanliness in the barn and dairy the number of organisms which get into the milk may be kept comparatively small. The statement of a dairyman that "one should make as careful a toilet for the milking yard as for the supper table" is no exaggeration. Of equal value in preserving milk, is the use of low temperature, and to be of the most use it should be applied *immediately* after the milk is drawn. When drawn from the cow, milk is at a high temperature, and indeed at just the temperature at which most bacteria will grow the most rapidly. Under the influence of the atmospheric temperature, especially in the summer, the milk will become cool very slowly, but never becomes cooler than the air. The bacteria which have gotten into the milk will therefore have the very best opportunity for rapid multiplication and the milk will sour very rapidly. If, however, the milk is cooled to a low temperature immediately after it is drawn, the bacteria growth is checked at once and will not begin again with much rapidity until the milk has become warmed once more. This warming will take place slowly, and therefore the cooled milk will remain sweet many hours longer than that which is not cooled. It frequently happens from this cause that a milkman finds that his morning milk will sour earlier than the milk of the night before. The milk drawn in the evening is put in a cool place at once and becomes quite cool during the night, while the morning's milk is at once put in cans and taken away for delivery. It will thus happen that the older milk will actually keep longer than the newer milk, simply because it has been cooled and must be warmed before bacteria can begin to grow very rapidly. A practical knowledge of this fact will be of great value to every person handling milk. Early cooling to as low a temperature as is practicable is the best remedy for too rapid souring of milk.

A second lesson of no less importance has been taught. All of the *abnormal* fermentations of milk, such as blue milk, red milk, slimy milk, etc., are also due to the growth of organisms in the milk, and *all* of these *may be prevented by care.* While the lactic organisms are so common and so abundant as to make it hopeless to try to keep them out of the milk, this is not true of the organisms producing the abnormal fermentations. These organisms are not so abundant, and by the exercise of care they may all be prevented from getting into the milk in such a way as to cause trouble. If a dairy is suddenly troubled with slimy milk or any other abnormal trouble, the dairyman may feel sure that the cause is to be found in some unusual contamination of his milk and that the remedy must be extra cleanliness. He need not look for the cause in the food that the cow has eaten, but may perhaps find it in the hay which the milker has handled or in the dust which has been stirred up in the milking shed. He must look for the trouble in something apart from the cow, and usually in his own carelessness, either in the barn or the dairy. Search in this direction will usually enable him to remove the trouble, while experiments upon the food or conditions of the cow will usually be worthless. Sometimes such troubles may be traced to an individual cow among a large herd. This will of course indicate that this cow has in some way become contaminated with a source of filth which produces the trouble. We must always remember that with a healthy cow all contamination of the milk must come from the outside, and the remedy is seen at once. Such a cow should be cleaned, and especial care should be taken to carefully wash her teats with a weak solution of acetic acid for the purpose of removing whatever bacteria may be clinging to them. Such methods will soon remove the trouble. The second lesson for the dairyman is, therefore, that *all abnormal fermentations may be prevented by sufficient care and cleanliness.*

It is well to notice that certain abnormal odors and tastes in milk may be produced directly by the food eaten by the cow. If a cow eats garlic or turnip the flavor of the milk is directly affected. Various other foods may in a similar manner affect the taste of milk, but this class of taints may be readily distinguished from those due to bacteria growth. The odors and taints due to the direct influence of the food are at their maximum as soon as the milk is drawn, never increasing afterwards. But the taints due to bacteria growth do not appear at all in the fresh milk, beginning to be noticeable only after the bacteria have had a chance to grow. If, therefore, a dairyman has trouble in his milk, which appears immediately after the milking, he may look for the cause in something thatthe cow has eaten; but if the trouble appears after a few hours and then grows rapidly worse until it reaches a maximum, he may be assured that the cause is some form of fermentation and that the remedy is to be sought not in changing the food of the cow, but in greater care in the management of the dairy or barn.

Various methods have been devised for destroying the organisms after they have found their way into the milk. Numerous chemicals have been used, and several methods of using heat have been devised. Into the details of this subject we can not go at present. The methods have been devised for the consumer of the milk rather than the dairyman, and the latter need not concern himself with them. The lessons for the dairyman to learn from the study of the fermentations of milk are scrupulous cleanliness in all affairs relating to milk care in the dairy, thorough washing with boiling water of all milk vessels, and low temperatures applied to the milk immediately after it is drawn from the cow.

BUTTER-MAKING.

To the butter-maker the bacteria of milk present a different aspect. To him they prove friends instead of enemies. After the cream is separated from the milk it proves of advantage to the butter-maker to allow bacteria to grow in it before churning. It is the custom of butter-makers to allow their cream to "sour" or "ripen" for a number of hours before churning. This is accomplished by allowing it to stand in a warm place for twelve to twenty-four hours. During this time the bacteria in it are multiplying rapidly and, of course, producing the first stages of the various forms of fermentation of which they are the cause. Prominent among them will be some of the lactic-acid organisms, and these will produce the souring of the cream. But the changes which occur are not confined to the lactic-acid organisms, for the warm temperature will hasten the growth of various other organisms which happen to be present in the cream.

The butter-maker finds certain advantages in such ripening. He finds that the cream will churn more easily and that he can get a larger amount of butter from a given amount of cream if it is ripened than he could if it were churned while fresh. He finds, further—and this is perhaps the chief value of ripening cream—that the butter made from ripened cream has a flavor superior to that of butter made from sweet cream. To obtain the proper flavor or aroma is one of the chief objects of the butter-maker.

Taking up the last matter first, we notice that the aroma is undoubtedly connected with the decomposition products of the bacteria growth. The volatile acids supposed to give flavor to the butter are not present in fresh milk, but only appear after standing, *i. e.*, after the fermentations have begun. For a time it was thought that the aroma of butter was due to some alcohol-like product formed during the ripening or to the presence of lactic acid itself. In accordance with this last idea lactic acid has been used artificially to ripen cream, but without much success. Of course, after we have learned that microörganisms have been forced to grow in the cream during the ripening, and when we combine this with the facts which we have learned of the fermentation products of microörganisms, we are led to believe that the ripening of cream is a more complicated process than the simple production of lactic acid. The first person to investigate this matter, in the light of modern discoveries, was Storch, a Swedish scientist. He assumed that the butter aroma was due to the growth of organisms and made a study of the bacteria in butter and cream for the purpose of finding, if possible, the proper species of organism for producing the aroma. After considerable search he finally succeeded in isolating from ripening cream a single bacillus, which seemed to produce the proper butter aroma when it was used in pure culture to ripen cream. Shortly after this Weigmann studied the same pheuomenon and also succeeded in obtaining cultures of an organism which produced a normal ripening and gave rise to a proper aroma. This ferment is coming into use in some of the creameries in Germany, the claim being made for it that it insures certainty in the result of the ripening process. It has not yet been introduced into this country for practical purposes.

The value of using such a ferment, if it can be supplied in a practical manner, is easily seen. It will introduce improvements into the creameries similar to those introduced into breweries by means of the study of yeasts. In normal butter-making as practiced to-day there is no way of obtaining any control of the bacteria present in the cream. A given specimen of cream will contain a large variety of bacteria. Conn has shown that there may be a score of different species of bacteria growing in cream which has been collected in the usual way. The butter-maker has no means of regulating this assortment or even of knowing anything about it, but must depend upon what has been brought to him. During the ripening process there will ensue a conflict of the different organisms with each other, and the result will depend upon a variety of circumstances. The result will be influenced by temperature, variety of species, quality of the cream, and length of time of ripening, as well as by the advantage which certain species of organisms may get from an earlier start. In such a conflict it will be a matter of accident if the proper species succeeds in growing rapidly enough to produce its own effect on the cream unhindered by the others. Now it certainly makes a great difference in the product what species of bacteria happen to grow most rapidly. Storch found only a single species that produced the proper aroma, and Conn has found that cream ripened with improper species of bacteria produces very poor butter.

The proper aroma of butter is a very intangible matter for study. It is not due to the volatile acids, as was formerly supposed, for the butter aroma has been found to be produced in solutions containing no butter fat. Evidently this aroma is in some way connected with the first products of decomposition which are set up in the cream as the result of bacteria growth. But these decomposition products are very numerous and not at all desirable. The bacteria which grow in ripening cream have been found to produce all sorts of disagreeable flavors and tastes in milk or cream if allowed to act unhindered. It seems to be only the first products of the decomposition that have the pleasant flavor, the later stages of the decomposition giving rise to products of a very different character. Too long a ripening results in the production of a butter containing too strong flavors, and one of the difficulties of butter-makers is to determine the right length of time for proper ripening. Indeed, the greatest difficulty which the butter-maker has to meet is in obtaining a uniform product. Proceeding according to rules which his experience has taught him, he can usually obtain a good product; but even the best butter-makers will sometimes fail from causes not explained.

Now, while the trouble is of course not entirely due to difficulties in the ripening, there is no question that this is one of the prominent sources of difficulty. The butter-maker can have no certainty that his cream is supplied with the proper species of bacteria to produce the proper aroma, and can never be sure as to the result of the ripening. If he could be furnished with a ferment for the purpose, as the brewer is furnished with yeast, one of his chief difficulties would be overcome. It is in this direction that experiments are being directed to-day. The bacteriologists have offered the butter-maker in Europe even now a ferment with which to ripen his cream, and by using fresh milk and separating the cream with the centrifugal machine there is nothing to prevent ripening cream with the ferment offered, unhindered by the other organisms which are usually present. But the work as yet is only preliminary. While there has been found a species of bacteria which produces a good result, we do not yet know enough of the effect of the ordinary species of bacteria. We have no knowledge as to whether more than a single species can produce good results, nor do we know whether the species used in creameries in this country and in Europe are one and the same.

The matter of the production of the proper butter aroma as the result of the use of artificial ferments in ripening cream is at present too uncertain for definite conclusions. We may be confident that the flavor of the butter is largely dependent upon the decomposition products of the bacteria that grow in the cream, and we have positive evidence that some organisms will produce much better quality of butter than others. We may hope that the further study of the decomposition products of different organisms and their relation to cream and butter will offer to the butter-maker the solution of this difficult problem in the future. If that occurs we may hope not that the butter-maker will be able to make better butter than the best that is made to-day, but that he will be able to obtain the best product with uniformity; and we may also expect that the creameries which at present make an inferior quality of butter will be able to improve it so as to compete with the best.

As for the other purposes of ripening, it is not possible to say much at present. Evidently the greater ease of churning and the larger product obtained from ripened cream are matters closely related to each other. The simple fact is that fat is more easily collected into masses of sufficient size to be removed mechanically from the buttermilk; but why the ripening makes them thus more easily collected is not yet fully explained. The difficulty of an explanation lies in the fact that we do not know exactly the condition of the fat in the milk.

The treatment of cream for butter-making needs, therefore, to be very different from the treatment of milk and cream for ordinary purposes. The milkman desires his milk to be as free from microörganisms as possible, but the butter-maker uses them and takes pains to cultivate them, but he wants the proper species if the bacteriologists can furnish them. He desires their action on the albuminoids of the milk, which renders the churning easier for him, and he desires still more the early products of their decomposition, which give him the desirable butter aroma.

CHEESE-MAKING.

If bacteria are desirable allies of the butter-maker, they are absolute necessities to the cheese manufacturer. Without their agency in ripening cream the butter, though it may taste flat, is still usable, but cheese is worthless without them. New cheese is not palatable; it tastes like fresh milk curd and is not at all pleasant. The proper flavor of cheese appears only as a result of a ripening process which is allowed to continue for several weeks or months, the flavor slowly growing stronger all the while.

The ripening of cheese has been conclusively proved to be a matter of the action of microörganisms. In 1875 Cohn first found bacteria in cheese. But it was Duclaux who first connected the ripening with the growth of these organisms. His first paper in 1877 gave the results of a chemical study of the ripening process and showed that it consists chiefly in the transformation of insoluble casein into soluble albuminoids and that the process is associated with the production of several ferments. Three years later he made a study of the bacteria in such cheese and determined that they are very numerous and comprise several species. In general the process of ripening is quite similar to the digestion by the digestive fluids of the stomach and alimentary canal. At this time Duclaux first suggested that certain of the bacteria produce ferments as the result of their growth similar in their characters to the digestive ferments, a discovery which has been well established by later work.

The ripening of cheese was now studied by others, but the most systematic work was done by Adametz. That ripening is due to bacteria growth was proved by this observer by treating fresh cheese with a disinfecting agent, which would prevent bacteria growth without affecting the chemical condition of the cheese. Under these conditions the cheese did not ripen. He also made quantitative estimates of the number of organisms present, finding from 25 to 165 millions per ounce, and this number was found to increase slowly during the ripening process. He also tried to determine whether ripening is due to the combined action of many species of organisms or to a single species. For this purpose he studied many specimens, and studied the cheese at intervals during the ripening. He found many species of bacteria present, but as the ripening went on one species was found to increase at the expense of the others and was much more abundant at the close of the ripening than any of the others. This species he always found, while the others were more variable, and hence he concluded that this species is the cause of the ripening. These results have since been confirmed.

At this point the knowledge of the normal ripening of cheese rests at the present time. But few observations have been made in regard to abnormal ripening. The greatest difficulty that the cheese manufacturer has to contend with lies in this direction. He can not be sure of a uniform product. In spite of all precautions his cheese will sometimes undergo abnormal troubles and become worthless by changes taking place during the ripening process. These troubles have been attributed to every sort of difficulty, including health and condition of the cow, the condition of the barn, the food of the cow, etc. In some cases they have actually been traced to filth connected with the management of the cows. Recent experiments have indicated that the direct result is in all cases to be attributed to the action of abnormal species of microörganisms which get into the milk, and hence have a share in the ripening of the cheese. Certain it is that black cheese, bitter cheese, and cheese flecked with red spots are all thus caused, and several other troublesome infections have with certainty been traced to microörganisms. But while abnormal ripening is undoubtedly due to growth of improper species of organisms, we can not at present determine how far the variations in the ripening are due to different species of organisms planted in the curd and how far to different conditions of the ripening. Each, doubtless, has its effect, and much further study is needed in this direction.

It is evident that the presence of bacteria in cheese is inevitable. The milk from which it is made always contains them, and when made into cheese part of the bacteria at least will be inclosed in the cheese. Here they find proper conditions for growth. The conditions are not very favorable, it is true, for the density of the cheese prevents ready access of air, and the organisms which require air for their growth suffer in consequence, except at the surface. The lack of moisture is also doubtless a disadvantage. But in spite of these disadvantages the bacteria grow slowly and soon produce profound chemical changes. They give rise to the peptonizing ferment, which acts upon the casein, rendering it partly soluble. Besides this, they induce numerous other decomposition changes, the total result of which is the production of the rich, delicately flavored cheese for the market. But though many chemical studies have been made of ripening cheese, we are not in condition at the present time to follow the process beyond stating the few salient facts already mentioned. The cheese-maker thus forces the bacteria to give him products for which he obtains a high price. Of course, so far as the food value of cheese is concerned, it is the casein and the fat which render cheese valuable, but its market price depends not upon the quantity of casein, but upon the flavor, and this flavor is supplied by microörganisms. To a certain extent also it is true that the different flavors of different cheeses are due to the action of different species of organisms in the ripening, although we know little in regard to this matter at the present time.

What the practical application of these results will be in the future, it is impossible to say. We have as yet only learned that there is a causal connection between the ripening and the microörganisms, but the conditions affecting their growth, the variety of species which can produce a normal ripening of cheese, whether different species of organisms will produce differently flavored cheeses, whether the cheeses of the markets are due to different organisms used in the ripening or chiefly to different conditions under which they are grown, are all problems to be settled before any practical results can be expected. But we can confidently predict one result: If we ever succeed in reducing the ripening of cheese to a systematic process and become able to use the proper species of organisms to produce it, we may expect an end of the cases of poisonous cheese of which so many instances are on record. The poisons in these cheeses are due to the growth of mischievous organisms, and will be avoided when we learn to ripen cheese with pure cultures of the proper species of bacteria.

We may then, perhaps, predict a time in the not distant future when both the butter-maker and cheese-maker will make use of fresh milk. The butter-maker will separate the cream by the centrifugal machine in as fresh a condition as possible and will add to the cream an artificial ferment consisting of a pure culture of the proper bacteria, and then ripen his cream in the normal manner. The result will be uniformity. The cheese-maker will in like manner inoculate fresh milk with an artificial ferment, and thus be able to control his product. Perhaps he will have a large variety of such ferments, each of which will produce for him a definite quality of cheese. To the dairy interest, therefore, the bacteriologist holds out the hope of uniformity. The time will come when the butter-maker may always make good butter and the cheese-maker will be able in all cases to obtain exactly the kind of ripening that he desires.

FARMERS' BULLETINS.

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 10.

CULTURAL
ERIMENT STATION
APR 19 1893

THE
RUSSIAN THISTLE
AND
OTHER TROUBLESOME WEEDS
IN
THE WHEAT REGION OF MINNESOTA AND NORTH AND SOUTH DAKOTA.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WASHINGTON:
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Farmers' Bulletin No. 9. Milk Fermentations and their Relations to Dairying. Prepared in the Office of Experiment Stations. Pp. 24. Issued July, 1892.

THE RUSSIAN THISTLE.

BY L. H. DEWEY.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF BOTANY,
Washington, D. C., January 12, 1893.

SIR: I have the honor of transmitting herewith a report on certain pernicious and troublesome weeds prevailing in Minnesota and North and South Dakota. Mr. L. H. Dewey, Assistant Botanist, was sent out last autumn to make observations and collect information relative to the nature and increase of these weeds, and to ascertain as far as possible the best means for their destruction. It is hoped that the information which he has embodied in this bulletin will prove to be of value to farmers in the section invaded by this pest.

Respectfully,

GEO. VASEY,
Chief of Division.

Hon. J. M. RUSK,
Secretary.

NAME.

The Russian thistle or Russian cactus is really neither a thistle nor a cactus. It is a saltwort, closely related to the tumbleweed, goosefoot, lamb's-quarters, and pigweed. Under any name, however, it is one of the worst weeds ever introduced into the wheat-fields of America. To the botanist it is known as *Salsola Kali* L. var. *Tragus* D. C. In some parts of Russia it is known as Tartar weed and Hector weed. Saltwort is its true English name, but to the farmers of the Northwest, who are best acquainted with the troublesome plant, it will probably continue to be known as the Russian thistle until finally exterminated.

DESCRIPTION.

The Russian thistle is an annual, coming each year from the seed. It grows from a single small light-colored root less than half an inch in diameter and 6 to 12 inches long to a height of 6 inches to 3 feet, branching profusely, and when not crowded forms a dense bush-like plant 2 to 6 feet in diameter and one-half to two-thirds as high. When young it is a very innocent-looking plant, tender and juicy throughout, with small, narrow, downy, green leaves. When the dry weather comes in August this innocent disguise disappears, the tender downy leaves wither and fall, and the plant increases rapidly in size, sending out hard, stiff branches. Instead of leaves these branches bear at intervals of half an inch or less three sharp spines, which harden but do not grow dull as the plant increases in age and ugliness. The spines are one-fourth to one-half inch long. At the base of each cluster of spines is a papery flower about one-eighth of an inch in diameter. If this be taken out and carefully pulled to pieces a small, pulpy, green body, coiled up and appearing like a minute, green snail shell will be found. This is the seed. As it ripens it becomes hard and of a rather dull gray color. At the earliest frosts the plants change in color from dark green to crimson or almost magenta, especially on the more exposed parts. When the ground becomes frozen and the November winds blow across the prairie the small root is broken or loosened and pulled out. The dense yet light growth and circular or hemispherical form of the plant fits it most perfectly to be carried by the wind. It goes rolling across the country at racing speed, scattering seeds at every bound, and stopping only when the wind goes down or when torn to pieces, for there are few fences or forests to stop its course in the Dakotas.

The saltwort or Russian thistle appears more like the common "tumbleweed" (*Amarantus albus* L.) than any other plant in the Northwest. It may be readily distinguished from the tumbleweed by the sharp spines in clusters of three each, the absence of flat leaves, denser growth, darker color, and by the red color in the fall.

TROUBLESOMENESS.

A weed is only a plant out of place or a useless plant taking the place of something useful. The Russian thistle, although rather pretty when reddened in the fall, and useful for forage when young, is always a weed. It will take possession of a field to the exclusion of everything else, and it draws from the land a large amount of nourishment that might otherwise go to make useful plants. In these respects it merely partakes of the properties of all weeds except that it spreads and multiplies more rapidly and hence takes more space and more nourishment.

Some of its special characteristics render this thistle much more troublesome than other weeds. It is armed with spines quite as sharp and much stronger than those of common thistles. Because of these it is difficult to drive horses through a field where the plants are abundant. In some sections the farmers find it necessary to bind leathers about the horses' legs while at work. Horses running in the pasture are often injured by having the skin on their legs badly lacerated. The spines breaking off under the skin cause festering sores. These sores are caused by the irritation, however, not by any poisonous property as is frequently supposed. Hunters find difficulty in getting their dogs to work well for prairie chickens in the stubble, and the dogs are sometimes injured by the sharp spines. Thrashers find it almost impossible to get gloves thick enough to keep the spines out of their fingers, yet thin enough to work with.

The Russian thistle is the worst rolling tumbleweed on the prairie, and in time of prairie fires is easily blown across a fire-break of any width, carrying fire to stacks and buildings. The weeds bank up against wire fences, causing them to be blown over by the force of the wind, and are sometimes carried into the groves on tree claims, making it impossible to cultivate. In this way, by forming a mulch, often several feet deep, they may do some good. When large and well developed they are bulky and stiff, making it very difficult to run harvesting machinery or even a plow. On railroad grades they prevent the growth of grass and other plants that would keep the banks from washing.

ORIGIN.

The Russian thistle originated in eastern Europe or western Asia. It has been known in Russia many years and has quite as bad a reputation in the wheat regions there as it has in the Dakotas. It was introduced in Bonhomme County, S. Dak., about fifteen years ago. Reports differ as to the method of its introduction. There is little doubt, however, that it was first brought there in very small quantities in flaxseed which was imported from Europe. There is evidently no foundation whatever for the theory, which is too often related as a fact, that it was first sown in South Dakota by immigrants either for forage or to inflict an injury on an enemy The few plants grown from the foreign seed grew, produced seed, and increased slowly and almost unnoticed until about six years ago (1886). They were then thoroughly acclimated and naturalized and seem to have partaken of the conquering spirit of the West.

MODES OF DISTRIBUTION.

The Russian thistles are most wonderfully adapted for spreading and covering new territory. As tumbleweeds they are carried for miles by the wind, scattering seeds as they go. By this means alone they often advance 5 or 10 miles in a single season. Single stray weeds may doubtless be blown much farther. The general advance is in the direction of the prevailing winds or the most frequent high winds, but the shifting breezes beat the plants about and seed all the area occupied. In many localities where a few plants were first seen four or five years ago every spot of land where the sod has been broken is now occupied. On every badger burrow and overfed spot in the prairie; on every roadside, railroad embankment, fire-break, and neglected garden; on every field of early-plowed land or stubble may be seen a patch of thistles. The seeds are not here and there, as with Eastern weeds, but they are everywhere. The few plants introduced four or five years ago have seeded the land for miles in every direction.

Plants are carried long distances on the railroads by stealing rides on the brake-roads and on the engine. They are also carried in the bedding or earth in stock cars. The seed is carried in flaxseed to considerable extent, but in none of the other grains raised in the West.

Wherever the plants or seeds thus carried by man are dropped they make new centers of growth, from which they may be scattered to the surrounding country by the wind. They grow larger and more abundant some years than others, but even during their off years they keep on spreading over new territory.

AREA COVERED.

The Russian thistles are now (1892) more or less abundant over all the region between the Missouri and "Jim" rivers in South Dakota and extending into North Dakota as far as the second tier of counties. They are found east of the "Jim" River along nearly every railroad, but have not yet become thick enough to be really troublesome in many places east of the "Jim" River Valley. About 30,000 square miles are infested with the weed, and it is abundant and really troublesome over about two-thirds of this area.

There are many scattered localities in States farther east where the thistles have been introduced but have not yet become abundant enough to cause much alarm. There are a few plants around the elevators and stock yards between Minneapolis and St. Paul, and an occasional one may be found along the Northern Pacific Railroad northwest of Minneapolis. Where this road crosses Gull River, in Todd County, Minn., quite a number of the thistles are growing. There are a few plants along the Chicago, Milwaukee and St. Paul Railroad just east of Sioux City, Iowa.

The real Russian thistle is not known west of the Missouri River. In the Black Hills, in South Dakota, and in many parts of Nebraska there is a saltwort (*Salsola kali* L.) which looks very much like the Russian thistle, but it is confined almost exclusively to saline localities and, so far, it has shown but little tendency to spread and become troublesome. This plant is also found in the tidewater region of the Atlantic coast, and it is probably this comparatively harmless form that is found in some parts of Wisconsin.

DAMAGE DUE TO THE RUSSIAN THISTLE.

In the badly infested area more than 640,000 acres are devoted to wheat-raising. The average loss on this land that may be attributed to the Russian thistle alone can not be less than 5 bushels per acre, and 3,200,000 bushels of wheat at the minimum price of 50 cents per bushel (which is considerably less than the average price) indicates a loss to the farmers in the two Dakotas of $1,600,000. The loss in other crops, the injuries caused by the spines and the fires caused by the plants jumping fire-breaks will bring the total loss to something more than $2,000,000 for the year 1892.

These figures may seem alarming, but they are based on conservative estimates. If they are alarming to the farmers it is well, for it is only when alarmed that most men will take effective measures to avoid danger.

CONDITIONS FAVORABLE OR UNFAVORABLE TO GROWTH.

Russian thistles grow best on high and dry land, where they are not too much crowded by other plants. They are seldom seen in sloughs or low land and make no progress in the native prairie except where the sod has been broken by badger burrows, or by overfeeding and tramping of cattle on some of the ranges. They are less numerous and robust in wet seasons than in dry ones, not so much because they can not stand wet weather, but because they are more crowded by other plants. Some Russian thistles growing on the bank of an irrigating ditch, with their roots almost in the water, made a larger and more vigorous growth in the dry season of 1891 than others about them in dry soil. At Minneapolis this year (1892) the rainfall was 45 inches before the end of September, yet the few thistles there were growing well.

The thistles appear to grow equally well in alkaline soil and in soil that is not alkaline at all. So far as the amount of rainfall or alkaline quality of the soil is concerned the Russian thistle may grow anywhere in the temperate zone.

The absence of trees and fences, the strong winds, and the methods of farming are particularly favorable to its distribution and growth in the Northwest. Wheat after wheat, with an occasional barren (or weedy) fallow, but no cultivated or hoed crops, gives but little opportunity to clear the land of troublesome plants. A few very profitable crops have induced the farmers to break up more land than they can work well. Wheat is sown over a large number of acres, sometimes merely drilled in on the furrow, or even in unplowed stubble land, and very frequently sown with insufficient cultivation of the soil. Where whole sections or even townships are one continuous wheat field, an acre here and there grown up to weeds, so as to be not worth the harvesting, does not seem to cut much figure in the total amount, and the weeds are allowed to grow and ripen seed to cover a larger area the next year. The thistles begin to grow large and coarse and to ripen seed soon after harvest; but at this time, when they most need attention, the farmer finds it difficult to get help enough to secure his wheat crop, and the weeds are left to take care of themselves, which they do to perfection.

Plowing in the spring or early summer is especially favorable to the growth of the Russian thistles, since they can get a good start in July and, being able to stand dry weather better than other plants, they take complete possession of the soil. Land broken up in spring or early summer is liable to be covered with the plants in August, for the seed is everywhere in the prairie grass and only waits for the sod to be broken that it may grow.

A hard frost early in the fall kills many Russian thistles before the seeds are ripened and therefore reduces the number of plants the following season. The comparative decrease in the number of plants during the present season is doubtless due to an early frost in the fall of 1891. The small size and less vigorous growth is due to the excessive rains early in the season.

WILL NOT RUSSIAN THISTLES DIE OUT OF THEMSELVES?

This question is frequently asked, and there really seems to be some grounds for the hope. In every locality the plant is less troublesome this year (1892) than it was last year. Causes for this have just been given. In many instances it has been noticed that in small patches, where the ground has become thoroughly seeded with the pests, they come up too thick to grow in their ordinary spreading habit, and, becoming slender and spindling, are quite unfit to roll about as tumbleweeds. There is no record, however, of their becoming so thick over any large area that some plants did not find room to develop into very good tumbleweeds. What is true of small patches is only partially true of large areas.

There are a few examples known where foreign weeds have been introduced into this country and have spread so rapidly as to cause considerable alarm for a few years, and afterwards have died out of themselves, or, at least, have ceased to cause trouble. There are numerous instances where weeds have been troublesome for many years and are still causing trouble in all infested regions except where the farmers, by combined action and determined effort, have exterminated them. There is indeed a possibility that the Russian thistle may die out of itself, but there is a greater probability that it will not only continue to grow, if allowed to do so, and to cause much damage in its present area, but that it will spread elsewhere. There is a certainty that if thorough measures be taken to stamp it out of existence it may be killed and will cease to be troublesome anywhere.

REMEDIES.

Plow in August or early September, before the Russian thistles have grown large and stiff and before they have gone to seed, using care that all weeds are well turned under. If the season be long and weeds come through the furrow it may be necessary to harrow the land before winter. Burn over stubble fields as soon as possible after harvest. Cut the stubble with a mowing machine if the fire does not burn everything clean without cutting.

Cutting the stubble and thistles before the latter have gone to seed will help, but is not thoroughly effective without fire, as the thistles will send out branches below where the mowing machine cuts them.

If the weeds have been neglected and have grown large and rigid, as they do by the middle of September, especially on neglected barren fallow or spring-plowed breaking, they may be raked into windrows and burned. The old-fashioned revolving hayrake or any rake made especially strong so as to pull the weeds, and especially good at clearing itself in dumping, will answer the purpose. An ordinary wheel hayrake with a set of strong teeth has been used successfully. This method is to be recommended only as a last resort, for by the last of September some of the seeds will be ripe enough to shell out and will escape being burned with the plants. If left until October, when many of the plants are certain to be fully ripe and dry, the land where they are growing will be well seeded any way; but raking together and burning the weeds will prevent their being blown across neighboring fields during the winter. Of course care should be taken to do this work when there is little wind, for a burning Russian thistle before the wind will jump any fire-break and carry both seeds and fire.

Barren fallowing does very well if kept barren by thorough cultivation. It gives but little benefit to the land, however. A much better method is to sow clover, millet, or rye, pasture it and plow it under green. This will be beneficial to the land, especially if a comparatively large proportion of clover is used, and the weeds will be choked out. Millet and oats combined may be grown and cut for hay. This crop will choke out nearly all the weeds, and the few that do grow will be too slender to cut any figure as tumbleweeds.

Corn, potatoes, beets, or any cultivated crop, *well taken care of*, will in two years rid the land of not only the Russian thistles, but nearly all other weeds.

Sheep are very fond of the Russian thistle until it becomes too coarse and woody. By pasturing the sheep on the young plants they may be kept down and the only valuable quality the plant has may be utilized.

In fields where the weeds are thick drag with an iron harrow, hitching the team on by a long chain. As soon as the harrow is full of weeds set fire to them and keep dragging and burning. This scheme, although apparently somewhat chimerical, has actually been tried with success.

If the Russia thistle is to be kept out of the cultivated fields it must be exterminated along roadsides, railroad grades, fire-breaks, waste land where the sod has been broken, and, in fact, in all accidental places where it may have obtained a foothold.

The ordinary road machines may be used to advantage along the roadsides, the scraper being set so as to take as thin a layer of earth as possible and throw weeds and all to the middle of the track. A single trip each way with the road machine would be sufficient in nearly all places to take the weeds between the beaten track and the prairie grass, so that 15 to 20 miles a day could be easily cleaned. If this work be done in August, before the Russian thistles become too large and stiff, the work of the road scraper will be sufficient. Going over with a heavy roller, however, would not only improve the road, but would crush the weeds so that no occasional mature plant would be blown away. If the work is put off until September the weeds should be raked together and burned.

On fire-breaks, railroad grades, and odd places these and other noxious weeds may be killed by a judicious use of the mowing machine, scythe, hoe, rake, and fire.

RECOMMENDATIONS.

Place a Russian thistle in each school-house, so that the pupils may become familiar with it, and teach them to kill it wherever they find it as they would kill a rattlesnake.

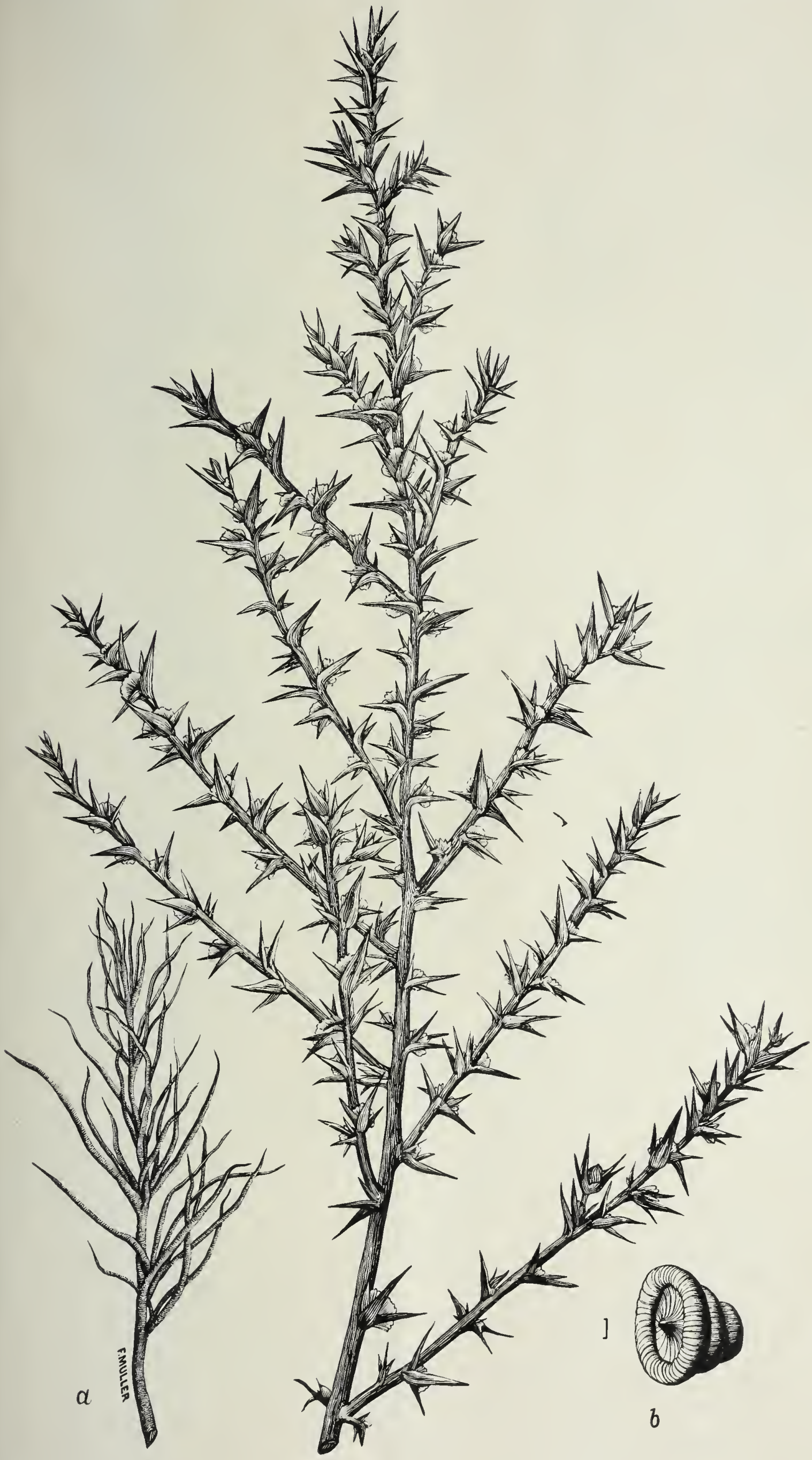
Permit no Russian thistle to go to seed. The plant is an annual; the seeds are evidently short-lived; hence if no plants are permitted to go to seed for two years the weed will in all probability be exterminated.

Let no one break up more land than he can take care of or more than he can properly cultivate.

Let each farmer first keep down all the weeds on his own farm and then insist that his neighbor do likewise.

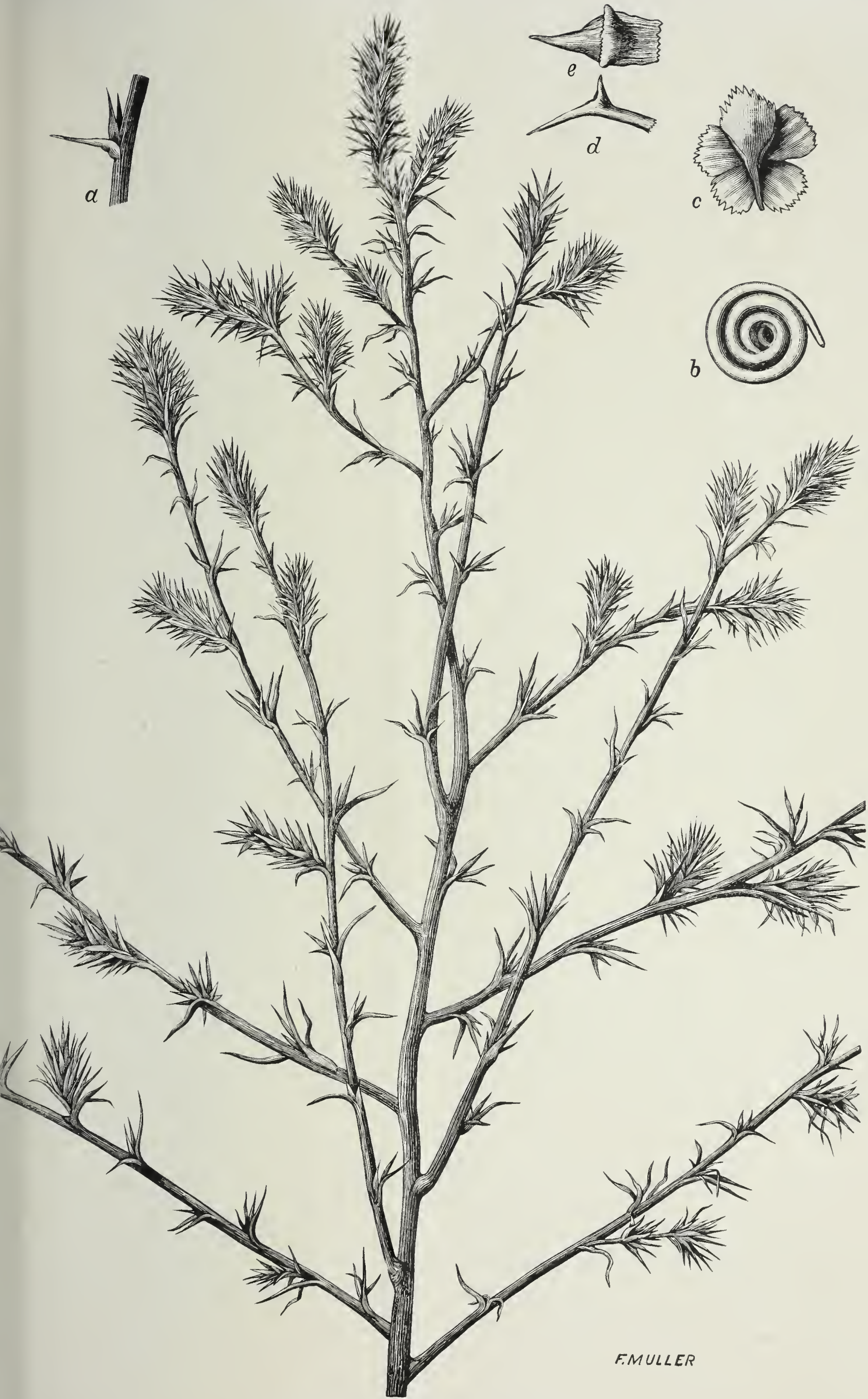
A little careful legislation that will touch up the careless farmer, the nonresident landowner, and the railroad companies would aid considerably in the solution of the question.

Be careful that all seed sown be as pure and clean as the modern fanning-mill can make it. Use especial care in regard to flaxseed and millet or any of the smaller and lighter seeds.



MATURE RUSSIAN THISTLE.

PLATE II.



RUSSIAN THISTLE BEFORE FLOWERING.

NOTES ON OTHER TROUBLESOME WEEDS.

MUSTARD FAMILY.

Many species of the mustard family are very troublesome in the wheat-growing region. The plants themselves are very hardy, starting early in the spring and withstanding the cold until late in the fall. Many of them produce seed during the greater part of the season. The seeds are abundant and small, but have wonderful vitality, sometimes remaining dormant in the ground several years and then growing when brought near the surface by the plow.

The most troublesome species belonging to this family are the wild mustard (*Brassica Sinapistrum* Boiss), treacle mustard or Western wallflower (*Erysimum asperum* D. C.), wormseed mustard (*Erysimum cheiranthoides* L.), false flax (*Camelina sativa* Crantz), Shepherd's purse (*Capsella Bursapastoris* Moench.), penny-cress or French-weed (*Thlaspi arvensé* L.), and peppergrass (*Lepidium intermedium* Gray). These are all annuals, and grow only in cultivated land or where the sod has been broken. Wild mustard, penny-cress, and peppergrass are more troublesome than the others in Minnesota and the Dakotas.

Remedies.—For the larger mustards in grain crops hand-pulling is the most practical remedy. If the land has become pretty thoroughly seeded, plow rather shallow and put in corn, beans, potatoes, or beets, or some cultivated crop. Cultivate the land as deep as it was plowed, so that all the seeds in the soil may be brought near the surface and have an opportunity to germinate some time during the season. Of course, care should be taken to prevent plants from ripening seed in the fall when the crops have been removed and the land is usually neglected. One season, if the work is well done, may be sufficient to clear the land of weed seeds; but cultivation for two years in succession is certain to be effectual.

PULSE FAMILY.

WILD LICORICE (*Glycyrrhiza lepidota* Nutt.).—This is probably one of the most troublesome members of this family in the Northwest. The plant grows 2 to 3 feet high from a perennial root, which is sweet to the taste. The leaves are compound, like those of the locust, with fifteen to nineteen leaflets. The pods are nearly an inch long, of a dark-brown color at maturity, and are beset with hooked prickles.

This plant grows mostly in the native prairie sod, but is nowhere very abundant. It is classed as a noxious weed because the prickly pods stick in sheep's wool and in the manes and tails of horses. Cutting or pulling the plants are perhaps the best remedies. Salt or coal oil on the roots may aid in killing them.

ROSE FAMILY.

WILD ROSE (*Rosa blanda* Ait.).—A perennial, woody plant 1 to 3 feet high, too well known to need description. It gives great beauty to the landscape in June, and, although it must injure the wheat to some extent both in yield and grade, the farmers do not complain much about it. They seem to prefer to lose a little wheat rather than call a rose a noxious weed.

The rose is abundant in wheat-fields and also in the native prairie. It is very hardy and deep-rooted, and withstands cultivation well; but deep plowing and thorough cultivation with corn, beans, or some cultivated crop will subdue it.

COMPOSITE FAMILY.

ROSINWEED (*Grindelia squarrosa* Dunal.).—A sticky, branching, perennial or biennial herb 2 to 3 feet high, with spherical heads and yellow blossoms. It grows in the native prairie, often so thick as to check the growth of grass.

GOLDENROD (*Solidago rugosa* Mill.; *S. nemoralis* Ait., and *S. Canadensis* L.).—The Goldenrods are too well known to need description. They are seldom regarded as troublesome weeds, but these three species often grow so thickly in the native prairie as to materially injure the pasture.

MARSH-ELDER (*Iva xanthiifolia* Nutt.).—This is an annual herbaceous plant, growing 5 to 10 feet high, and appearing very much like the great ragweed (*Ambrosia trifida*). It takes complete possession of the land if allowed to do so, even contending successfully against the native prairie grass. In the wheat-fields it does considerable damage unless the growth of wheat is vigorous enough to choke it down early in the season.

RAGWEED (*Ambrosia artemisiæfolia* L.; *A. trifida* L., and *A. psilostachya* D. C.).—These are well-known plants. The first two are annuals and more abundant in the North than the third, which has slender running rootstocks. They grow mostly in cultivated land, or at least where they do not have to contend against the prairie grasses, and often cause considerable loss in the wheat fields, especially where the wheat is slow in starting in the spring.

COCKLEBUR (*Xanthium Canadense* Mill.).—This is one of the worst weeds from Kansas and Nebraska to southern Minnesota and South Dakota. It grows in cultivated land, and makes good headway even in the native prairie. The prickly burs are very troublesome in regions where sheep are grazing.

WORMWOOD (*Artemisia biennis* Wild.).—Three or four species of wormwood are very common in Minnesota and the Dakotas, but the tall, slender, dark-green biennial wormwood seems to be the most troublesome. It takes possession of the land in wheat fields where the wheat is partly killed out or is slow in starting.

Remedies.—For those members of the composite family that are troublesome in pasture land, mowing before they go to seed, usually in July or August, will subdue them, and if kept down two or three years in succession the grass will become thick enough to choke out the few remaining plants.

For cultivated lands a little more thorough cultivation and less neglect during the last of the season will be found effectual.

AMARANTH FAMILY.

TUMBLEWEED (*Amarantus albus*, L.).—This weed is too well known to need description. In habit and general appearance it is like the Russian thistle, but is less dense, ripens seed earlier, has smaller and less rigid spines, and bleaches to a lighter color when it dries. The seeds are flattened, black, and shining, and not more than one-twentieth of an inch in diameter. Most of the remedies given for the Russian thistle may be applied to this weed, but it must be remembered that this is mature and off before the wind, and seeding the land a month earlier than the saltwort.

GOOSEFOOT FAMILY.

LAMB'S-QUARTERS, PIGWEED (*Chenopodium album* L.).—An erect, branching, herbaceous plant 2 to 4 feet high, from an annual root. The flowers are small, green, and densely clustered in spikes. The leaves are more or less toothed on the margins, and the whole plant is mealy. It grows mostly in uncultivated or waste land. Hand pulling or thorough cultivation will readily subdue it.

WINGED PIGWEED (*Cycloloma platyphyllum* Moquin.).—A coarse, much-branched, annual, herbaceous plant, blown about in the fall as a tumbleweed. The leaves are narrow and sinuate-toothed like those of the dandelion. The fruits have a continuous, membranaceous ring about them so that they may be carried by the wind to some extent independently of the plant. It grows only in cultivated land or waste places where the sod has been broken. Preventing the plants going to seed will soon subdue them.

RUSSIAN THISTLE, SALTWORT (*Salsola Kali* L. var. *Tragus* D. C.).—This troublesome weed is mentioned here only as a member of the goosefoot family.

BUCKWHEAT FAMILY.

DOCK (*Rumex salicifolius* Weinmann, *R. obtusifolius* L. and *R. Crispus* L.).—Coarse perennial herbs, too common in cultivated fields. The seed ripens at about the same time as spring wheat and usually comes from the thrashing machine with the grain. It is doubtless often sown with wheat unless the seed wheat is carefully cleaned.

Remedies.—Clean seed, hand pulling or grubbing with a mattock, and thorough cultivation. In small patches salt or kerosene on the roots may have the desired effect.

BLACK BINDWEED (*Polygouum convolvulus* L.).—This is a slender, climbing, herbaceous vine common throughout the wheat-growing regions all through the West. It injures the yield and the grade of wheat and often binds the grain together, making it impossible for the harvesting machines to do good work. The black triangular seeds are ripened about the same time as the spring wheat, and being but little smaller than the wheat kernel, often appear in the grain as it comes from the thrashing machine.

Remedies.—Clean seed, fall plowing, and thorough fitting of the ground. If the bindweed is very abundant put in a cultivated crop or a crop of millet and clover, to be turned under for green manuring.

GRASS FAMILY.

BARN-GRASS (*Panicum crusgalli* L.).—This is a coarse annual grass 2 to 3 feet high, with a panicle of three to eight dense spikes and 1 to 2 inches long. In the western form the panicle is almost always dark colored or nearly black at maturity, and the spikelets are short-awned or awnless.

In wet seasons it takes possession of the land where the wheat is slow in starting and either chokes it out entirely in low places or greatly reduces the yield and the grade. The seed, although less than one-half as large as the wheat kernel, often comes from the thrashing machine with the grain. A little more careful screening would readily take it out and save the farmer considerable in the price of thrashing.

Remedies.—Where it is thick, mow before it goes to seed. Tile-drain low places where the value of the land will warrant it.

SAND-BUR, BUR-GRASS (*Cenchrus tribuloides* L.).—This little grass, with its sharp, spiny burs, is well known. It is found in all parts of the United States except the high mountain regions, but is especially abundant and troublesome from Ohio to Kansas and Nebraska, extending into South Dakota and Minnesota. Its character as a noxious weed is due to the spiny burs which render it exceedingly troublesome in sheep's wool. It is an annual, and may be subdued in fields by cultivation or burning. To exterminate it, however, it must be prevented from going to seed in waste places.

PORCUPINE-GRASS, NEEDLE-GRASS (*Stipa spartea* Trin.).—A rather stout, erect grass 2 to 3 feet high, with strong, twisted awns 3 to 6 inches long, growing in tufts or small bunches, usually on rather dry knolls.

The sharp beak to the fruit and the retrorsely barbed awn cause it to work into sheep's wool and even pierce the skin, producing bad sores and not infrequently causing death. In hay the awned spikelets are very troublesome to horses, working into the nostrils, where the moisture causes the awns to untwist, producing a very disagreeable irritation.

The spikelets ripen and fall in June, so that the grass must be mowed early to prevent its going to seed. Where this grass is thick it would be advisable to plow up the land and, after subduing it with one or two cultivated crops, seed it with something more valuable than porcupine grass.

COUCH-GRASS, QUICK-GRASS, QUACK-GRASS (*Agropyrum repens*, Beauv.).—This grass is very similar in appearance to the wheat grass of the prairies, forming heads like the wheat grass, but seldom producing mature seed. It may be distinguished by its long, white root stocks, by which it is usually propagated. These root stocks are very tenacious of life and if broken to pieces every piece is likely to grow if left in the ground. Ordinary plowing and cultivation in the early part of the season helps to disseminate it and improve its growth rather than subdue it.

Throw the plow or cultivator out of the ground in crossing a patch of quack-grass in the field or small pieces of the rootstocks will be carried to scatter the grass to other places. Salt and sheep will subdue it. Fall plowing to turn the roots to the frost will check it. Plow deep, drag out the roots, and burn them. Follow any method by absolutely clean cultivation for the entire season.

SQUIRREL-TAIL, WILD BARLEY (*Hordeum jubatum* L.).—This grass is common throughout the region west of the Mississippi River. It is a bad pest in pasture and grass land, as it is worthless itself and it takes possession of the land best adapted to the production of the most nutritious grasses.

Mowing before it goes to seed may check its growth and will at least prevent its spreading. Cultivation and reseeding is the only sure method of getting rid of it.

GENERAL REMEDIES.

Do all that is possible to prevent weeds from going to seed.

Be sure that all seed, especially flax, oats, and grass seed, be thoroughly cleaned before it is sown on the land.

Fit the land thoroughly so that wheat, oats, or rye may have as a good a chance to grow as the weeds that are already in the soil.

When cultivated or hoed crops are raised, cultivate them well and do not allow a crop of weeds to grow after the corn or potatoes have been taken off. If the fertility of the soil and the length of the season will warrant two crops in a single year, let both crops be useful.

A crop of weeds turned under green enriches the soil and decreases the store of weed seeds by at least so many as the number of plants turned under, while a crop of weeds grown to maturity drains the soil of fertility and adds many times the number of plants to the store of seeds for future weeds.

DESCRIPTION OF PLATES.

PLATE I. Branch from Russian thistle, showing the appearance of the plant when the seeds are mature: *a,* Branch from a young plant, showing the appearance before the dry season; *b,* Mature seed enlarged five times.

PLATE II. Branch of Russian thistle, showing the appearance before flowering and before the spiney branchlets have elongated: *a,* Spines enlarged; *b,* Young grain with the covering removed, enlarged about seven times; *c,* Blossom removed from the axil and viewed from below, enlarged about four times; *d,* Section of fruiting calyx, side view; *e,* Same, seen from above.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 11.

THE RAPE PLANT:

ITS HISTORY, CULTURE, AND USES.

BY

THOMAS SHAW,

Professor of Agriculture in the Ontario Agricultural College.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

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FARMERS' BULLETINS.

The bulletins of this series may be obtained by applying to the Secretary of Agriculture, Washington, D. C. The following have been previously issued:

Farmers' Bulletin No. 1. The What and Why of Agricultural Experiment Stations. (A brief explanation of the object, origin, and development of the stations, their work in Europe and in the United States, and the operations of the Office of Experiment Stations of the Department of Agriculture.) Prepared by the Office of Experiment Stations. Pp. 16. Issued June, 1889.

Farmers' Bulletin No. 2. The Work of the Agricultural Experiment Stations. (Illustrations of station work in the following lines: Better cows for the dairy; fibrin in milk; bacteria in milk, cream, and butter; silos and silage; alfalfa; and field experiments with fertilizers.) Prepared by the Office of Experiment Stations. Pp. 16. Issued June, 1889.

Farmers' Bulletin No. 3. The Culture of the Sugar Beet. (Treats of the climatic conditions, soil, fertilizers, and cultivation required by the sugar beet, cost of growing, time to harvest, and method of siloing; describes briefly the process of beet-sugar manufacture, and gives statistics of sugar production and consumption.) By H. W, Wiley, Chemist of the Department of Agriculture. Pp. 24. Issued March, 1891.

Farmers' Bulletin No. 4. Fungous Diseases of the Grape and their Treatment. (Describes downy mildew, powdery mildew, black rot, and anthracnose of grapes, and gives instructions for their treatment and estimated cost of remedies.) By B. T. Galloway, chief of the Division of Vegetable Pathology. Pp. 12. Issued March, 1891.

Farmers' Bulletin No. 5. Treatment of Smuts of Oats and Wheat. (Describes the smuts of wheat, oats, and barley, the damage they cause, and the various methods of treatment which have been found useful for their prevention.) Prepared by the Division of Vegetable Pathology. Pp. 8. Issued February, 1892.

Farmers' Bulletin No. 6. Tobacco: Instructions for its Cultivation and Curing. Prepared by John M. Estes, special agent. Pp. 8. Issued February, 1892.

Farmers' Bulletin No. 7. Spraying Fruits for Insect Pests and Fungous Diseases, with a Special Consideration of the Subject in its Relation to the Public Health. Prepared by the Divisions of Entomology and Vegetable Pathology. Pp. 20. Issued April, 1892.

Farmers' Bulletin No. 8. Results of Experiments with Inoculation for the Prevention of Hog Cholera. By D. E. Salmon, chief of the Bureau of Animal Industry. Pp. 40. Issued May, 1892.

Farmers' Bulletin No. 9. Milk Fermentations and their Relations to Dairying. Prepared in the Office of Experiment Stations. Pp. 24. Issued July, 1892.

Farmers' Bulletin No. 10. The Russian Thistle and other Troublesome Weeds in the Wheat Region of Minnesota and North and South Dakota. Pp. 16. Issued April. 1893.

THE RAPE PLANT: ITS HISTORY, CULTURE, AND USES.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., May 22, 1893.

Sir: I have the honor to transmit herewith, for publication as a Farmers' Bulletin, an account of the history, culture, and uses of the rape plant, prepared by Thomas Shaw, professor of agriculture in the Ontario Agricultural College, who has conducted a number of important experiments with this plant, and has carefully studied the requirements for its culture in North America. There is good reason to suppose that in many sections of the United States it would be a useful addition to the crops now grown.

Respectfully,

A. W. Harris,
Director.

Hon. J. Sterling Morton,
Secretary of Agriculture.

NEED OF THE RAPE PLANT IN THE UNITED STATES.

Indian corn is unquestionably one of the most useful fodder plants ever bestowed by a kind Providence on the inhabitants of any country, and its value in this respect continually increases with the multiplication of silos. This continent, with its dry and hot summers, would be immeasurably worse off than it is for fodder supplies in the autumn when the pastures fail were it not for the abundance with which corn can be produced. But there is still a season after the corn has been harvested, and before the setting in of winter, during which we must depend solely upon grass as a source of food for our flocks and herds; otherwise we must draw upon winter stores to feed them. The need of some useful fodder plant that will furnish abundant supplies of nutritious pasture at that season has long been recognized, more especially by the farmers of the East, where the pasture grounds are much more circumscribed than in the great West. And this want has been more severely felt in the case of sheep than in that of cattle, owing to the greater difficulty in providing them with suitable supplemental foods at that season. In consequence, millions of sheep and lambs are put upon a slaughter market during the autumn months in an unfinished condition, to the great loss of the owners, and in the end to the great loss of the nation.

In the judgment of the writer, the Dwarf Essex rape is a plant which can be easily grown in many portions of the United States, and which will furnish abundant supplies of succulent, rich, and nutritious pasture at a season of the year when it is sorely needed; and it may be mentioned here that this judgment is based upon a somewhat extensive and intimate experience in growing rape in various ways in recent years, as will be shown in another division of this article.

DESCRIPTION AND HISTORY OF THE RAPE PLANT.

From the nature of the many questions received by the writer from various parts of the continent it is evident that many persons do not even know what the rape plant is. A brief reference, therefore, to the plant and to its history will be in order.

Rape, of the cruciferous genus *Brassica*, is a plant which in the early stages of its growth can not easily be distinguished from the numerous varieties of Swede turnips that are now grown. It usually attains a greater height than the turnip, and has more of stem and leaf growth. But there is a marked contrast in the habits of root growth between these two species of plants; whereas in turnips the roots are bulbous, in rape they are fusiform and stringy. ·The leaves and stems of rape are the only portions of the plant of any use in furnishing food.

Rape, of which there are several varieties, has long been grown in Europe and other countries, more especially for the oil which is extracted from its seeds, and which is used chiefly for purposes of lubrication and lighting. Several of the species comprise both summer and winter or annual and biennial varieties, the latter being considered more productive of seed than the former. In England and Scotland some of the winter varieties of rape are sown in the early summer and are pastured off by sheep and lambs in the autumn following. The plants are then allowed to mature their seeds the second year. This is notably the case with the Dwarf Essex, the only variety which thus far has proved a marked success on this continent.

The rape plant grows slowly at first, but after a time it pushes ahead rapidly where the conditions are suitable and a large amount of succulent and nutritious foliage is produced. An average crop grown in drills should furnish not less than 10 tons per acre, and when the conditions are all favorable it would be quite possible to produce at least 20 tons of green fodder per acre.

Rape is possessed of remarkable fattening properties. The nutritive ratio of green rape as given by Wolf is 1 : 2.9, while that of red clover in blossom is only 1 : 5.7. When sheep and lambs are turned in upon it, to use a common but expressive phrase, "they soon weigh like lead."

THE RAPE PLANT IN CANADA.

While rape of the Dwarf Essex variety has been grown as a pasture crop in Canada for several years past, it is true, nevertheless, that its growth has until quite recently been narrowly circumscribed. That so useful a fodder plant should not have been introduced at an earlier period may seem strange in a country settled chiefly by people of Anglo-Saxon descent, and that after it had been introduced it did not attract more attention may also evoke some surprise. The explanation will probably be found in the large areas occupied in proportion to the number of sheep kept, in the extent to which grain-growing on virgin soils has arrested the attention of the people, and in the inherent constitutional conservatism of the mind of the average farmer.

INTRODUCTION OF THE RAPE PLANT INTO CANADA.

It is not known when rape was first introduced into Canada, but it is now certain that it has been grown for several years past in the county of Wellington and in one or two of the adjoining counties. In other portions of the Dominion it does not appear to have been grown to any considerable extent, if indeed at all. However, since the bulletins upon rape culture were first issued by this station, it has been ascertained by actual test that rape can be grown in fine form in every province of Canada. A large percentage of the Canadian lambs shipped during the more recent years to the Buffalo market have been finished on rape.

EXPERIENCE WITH RAPE AT GUELPH, CANADA.

The writer was placed in charge of the department of agriculture at the Ontario Agricultural College, Guelph, Canada, in the autumn of 1888. Before that time, so far as can now be ascertained, rape had not been grown upon the farm during any period of its history as an agricultural experiment station. As the farm at that time was infested in an annoying degree with various forms of noxious weed life, the rape plant, it was judged, would prove helpful in cleaning it, owing to the late season at which it might be sown, and to the further fact that it required cultivation to grow it in finest form at a season of the year when such work would be peculiarly fatal to weeds. It was introduced, therefore, at first, with this object primarily in view. In 1889 twelve acres of rape were grown at this station. It was sown on ground where thistles grew thick and rank and strong until the middle of June, when they were plowed under, the rape being sown in raised drills that had been formed soon after the land had been plowed. It was pastured off with lambs, and but few thistles were found the following year in the oat crop that came after the rape.

In 1890 fifty-four acres of rape were grown after a crop of rye, a portion of which had been made into silage early in June, and the residue had been cut in the green state with the binder and cured for winter fodder. In the autumn of that year 537 sheep and lambs were fattened upon the rape, 18 head of steers fed upon it for fifty-nine days, and several acres were still left uneaten when winter came.

The following year (1891) one person in thirty-five hours with the spud removed all the noxious weeds from 46 acres of the grain crop that followed the rape. This work was done in the month of June.

In 1891 some 40 acres of rape were grown. It also came after rye, which had been cut about June 1 and cured for winter fodder. About 6 acres were also grown as a catch crop after the grain grown upon the land had been removed. No fewer than 666 lambs pastured upon it for from two to two and one-half months.

In 1892 about 48 acres were grown, but the seed sown on fully two-thirds of this acreage proved untrue to name. It was a hybrid variety, to which further reference is made in the next section. It was not valuable as a pasture, hence we purchased only 376 lambs in 1892, and found that number sufficient to feed off all the rape thus grown, and in addition several acres of the true variety grown as a catch crop after winter wheat.

A large number of plats have also been grown each year by way of experiment. These include the following tests:

(1) Rape grown on different kinds of soil with and without salt; (2) rape grown in drills as against flat cultivation; (3) rape grown in drills as against broadcast seeding; (4) rape grown in drills different distances apart; (5) using different quantities of seed per acre; (6) thinning the plants to different distances in the drills; (7) applying various fertilizers; (8) feeding lambs upon rape grown after a grain crop; (9) testing the amount of pasture furnished by a single crop of rape grown under favorable conditions; (10) pasturing lambs upon rape alone, rape with a supplement of oats, and rape with access to a grass pasture; (11) pasturing swine upon rape alone and with other food adjuncts; (12) feeding rape as a soiling crop to cows giving milk and to various other animals.

Definite results have not been reached as yet in all instances, but up to the present the indications are as follows: (1) That on certain soils salt is a valuable fertilizer for rape; (2) that flat cultivation in drills will probably give somewhat larger returns than ridge cultivation; (3) that larger crops can be obtained from rape sown in drills rather than broadcast; (4) that the distance between the drills is largely dependent upon the soil and the time of sowing; (5) that rape of a superior quality is grown where the plants are not much crowded in the drill; (6) that when not more than 2 pounds of seed per acre are used hand-thinning in the line of the drills will probably not repay the outlay; (7) that nitrate of soda on some soils has a markedly favorable influence on the growth of the plants; (8) that in some seasons a good crop of rape can be grown after a crop of winter wheat has been removed; (9) that under favorable conditions enormous crops of rape may be grown; (10) that oats do not seem to render much service when fed along with rape that is being pastured by lambs, and that rape and old meadow pasture are superior to rape alone as a pasture for lambs; (11) that rape makes an excellent food for swine when supplemented with more concentrated foods; (12) that rape may be fed under certain conditions to cows giving milk.

Several other phases of the rape problem are being studied at this station, but these may not even be noticed here. It may be advantageous, however, to mention (1) that in our experience of growing rape for four years we have found that 1 acre will pasture 10 to 16 head of lambs from two to two and one-half months, when rye grown for fodder has preceded the rape the same season; (2) that when grown on ground that had not been cropped previously the same season, all the conditions being favorable, we found that 1 acre of rape would pasture 36 to 37 head of lambs for two months; and (3) that the lowest average gain per month made by any considerable number of lambs when pasturing upon rape alone was 7.80 pounds, and the highest 12.60 pounds.

In March, 1891, Bulletin LX, on "The Uses of Rape," was issued by the agricultural department of this station. This bulletin was the first that had appeared on the subject in America. It was followed by another in June, 1892, and so great has been the demand for these that long ago the supply of both was quite exhausted.

DIFFERENT VARIETIES OF RAPE.

By way of experiment three varieties of rape were grown at this station in 1892. These were labeled, respectively, "Dwarf Essex or English Rape," "Broadleaf Dwarf Essex," and "German or Summer Rape." There are good reasons for believing that the variety mentioned second, which is evidently a hybrid, has not been correctly named.

The Dwarf Essex or English variety has already been referred to as the only kind of rape which has hitherto proved a success as a fodder plant in North America. Fig. 1 represents a plant as it appeared when taken from the line of one of the rows in the field last autumn, when it had ceased to grow for the season.

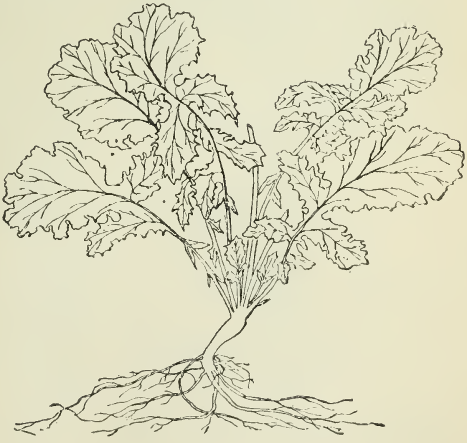

Fig. 1.

The leaves of this variety commence to branch near the surface of the ground, and they extend in every direction until the entire surface of the soil becomes hidden by a mass of foliage, which varies from 1 to 3 feet in height, according to the soil and season.

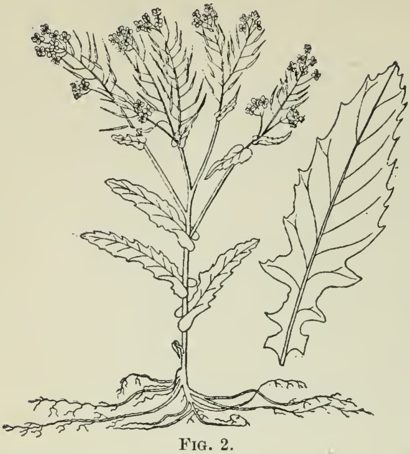

Fig. 2.

The proportion of the stem to the leaves is not nearly so great as in the other varieties shown in Figs. 2 and 3, and it should not produce any blossoms the first season.

The hybrid, or so-called Broadleaf Dwarf Essex, can not be easily distinguished from the true Dwarf Essex during the first weeks of its growth, but after a time the flower-stalk pushes upward. It grew to the height of about 3 feet at this station, and the blossoms began to appear in from six to eight weeks after it was sown. This hybrid variety, which unfortunately was so generally sown in 1892, has been incorrectly represented by various writers as being the same as the Bird Rape.

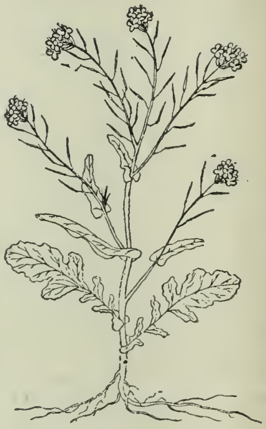

Fig. 3.

The variety of rape represented in Fig. 2 is probably not more than one-third as valuable for producing fodder as the true Dwarf Essex. It grows far too much stalk in proportion to the foliage, and the stalk soon becomes so woody that sheep will not eat it, but when turned in upon it they soon strip off the blossoms and seed pods.

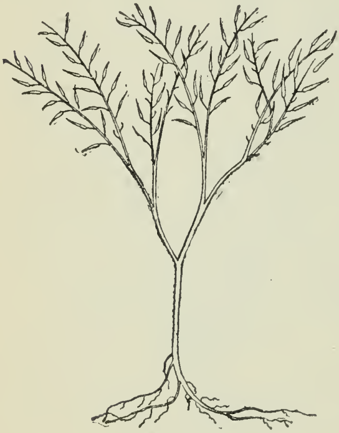

Fig. 4.

The German or Summer Rape, or as it is more frequently called Bird Rape, differs materially from the varieties shown in Figs. 1 and 2. It differs from the former in the lighter tinge of the leaf, in the small amount of foliage which it produces, and in its running to seed the same season that it is sown. It differs from the latter in its less vigorous growth, in its being more branched, and in the smaller size of the seed pods. Fig. 3 represents a plant of the German or Summer Rape which grew in the greenhouse, as it appeared about eight weeks after the seed had been sown. Fig. 4 represents the same variety of rape when fully matured, as it appeared in the field plat last autumn. This kind of rape is of no use for pasture.

THE RAPE PLANT IN THE UNITED STATES.

Rape does not appear to have been grown as yet to any great extent in the United States for any purpose. This is rather surprising when we consider the need there is for such a plant on this continent, where climatic and other conditions do not admit of growing turnips and folding sheep upon them as in Great Britain. The writer has been unable to trace the growth of rape in a large way in the United States beyond six or seven years; and yet there can be but little doubt that it has been grown there to some extent for at least a century by individuals in various localities. The explanation is found probably in the great extent of the grass pastures in comparison to the numbers of the sheep grown and in the relatively subordinate place that has hitherto been given to the production of mutton.

ADAPTABILITY OF LARGE AREAS.

The writer has no doubt whatever but that very large areas in the United States are preëminently adapted to growing rape in fine form. The soils of the great prairies will doubtless be found suitable for this crop where the summers are not too dry and warm. And in large sections in all parts where the climatic conditions resemble those of Ontario it will doubtless be found that rape will grow readily. This would mean that rape can be successfully grown in all the States bordering on the Dominion of Canada and in several of those that lie further to the south. Whether it would furnish winter pasture in the more southerly States and whether it would grow seed as a paying crop in these can be determined only by actual test. The heat of the sun in such latitudes would doubtless be fatal to its successful growth in midsummer.

EXPERIENCE IN GROWING RAPE IN THE UNITED STATES.

The testimony given below in reference to growing rape has been directly communicated to the writer by the parties whose names are mentioned. This testimony relates to eight different States, and would have embraced a much larger number but for the fact that nearly all the seed sown in 1892 in the various divisions of the Republic was not true to name. The States referred to are Maine, New York, Pennsylvania, Ohio, Michigan, Wisconsin, Illinois, Minnesota, and South Carolina.

In Maine 3 acres of rape were grown in 1892 by H. R. Gilman, of Exeter. He thinks he is safe in saying that it was the first ever grown in that

State. It was a variety which blossomed. It was sown on an overturned sod after the removal of the hay. The seed was broadcasted July 5, along with 100 pounds of superphosphate per acre. It all grew nicely, but best where the superphosphate had been most freely applied. The first week in September 50 lambs were put upon it and 50 others three weeks later. They did well on it until the middle of October. This, of course, was the hybrid variety, and yet Mr. Gilman says in regard to it: "I think it fully repaid me for the labor. The lambs ate it, seed, stalk, and all. They seemed to prefer it to good clover feed."

Rape has been successfully grown in New York for a longer or a shorter period by A. Bordwell, of Fargo; Frank D. Ward, of South Byron; C. D. Smead, v. s., of Logan; and E. D. Rumsey, J. H. Potter, and John E. Young, all of Batavia. The names of other growers could be added were it necessary.

Mr. Bordwell has grown English rape for six or seven seasons. He sows in drills 30 inches apart, and gives level culture; sows as early as the middle of April, and then again in May and June. The first sown plats are ready for a second cutting by the time the June sowed crop has been fed. He uses it as a soiling crop in fitting sheep and lambs. He says in regard to it: "Have had good success every time. When 18 inches in height the leaves covered the ground."

Mr. Ward grew the true Dwarf Essex rape in 1891 and 1892; sowed it broadcast with the clover seeder on land thoroughly summer fallowed early in the season and manured, covered it with the Thomas smoothing harrow, and then rolled it. For soiling purposes he sows it from April to July, and for pasture from June 20 to July 1; he uses it as pasture for sheep and lambs, and as a soiling crop in fitting show sheep. To the above Mr. Ward adds:

> I have had excellent results—a great growth of nutritious food which bridged over the dry season and kept lambs and show sheep thriving. Rape can not be too highly recommended. It is much superior to any other green food that I know of. I have been laughed at a great deal for sowing my "turnips" so thickly, but when I had tons of excellent fodder, while the critics had nothing but bare timothy for their lambs, the laugh was changed. The best farmers are now sowing considerable rape.

Dr. Smead grew the Dwarf Essex in 1891, and obtained a fine crop. In 1892 the variety sowed by him blossomed, and he considers it only about half as good as the Dwarf Essex. He believes that about May 20 is the best time to sow for August pasture, and in July for late fall pasture. He pastured lambs upon it after weaning, and breeding ewes later. He adds: "I consider it a most valuable dependence during a dry season or as a late fall pasture for sheep."

Mr. Rumsey grew 20 acres of rape on rather poor ground in 1892; sowed the seed about July 15, and the rape was ready for pasturing in September; mixed the seed with ammoniated phosphate, and sowed in rows with the grain drill at a distance of 28 inches apart; used 2 to 2½ pounds of seed per acre, and about 125 pounds of phosphate. In summing up Mr. Rumsey states: "I have an Englishman working for me who says he never saw better rape in England. I pastured 200 lambs on it in September, October, and until the middle of November. I think it very valuable."

Mr. Potter grew the Dwarf Essex rape in 1892. He sowed it on overturned sod land about the end of June, using 4 pounds of seed to the acre, and says in regard to it: "Rape is the best food I ever saw for sheep."

Mr. Young grew 8 acres in the summer of 1892. He sowed it on sod land overturned; used a grass-seed sower and put in the seed about July 10. He put 290 lambs on the 8 acres on September 16, and it provided pasture for them until November 8; but it should be mentioned that during the last week or two they had some pasture in addition. Within the period mentioned they gained 18½ pounds each. "I am so well pleased with it," says Mr. Young, "that I can not speak too highly of it."

In Pennsylvania rape was grown in 1892 by John I. Gordon, secretary of the American Hampshire Down Association, and by W. A. McCoy, both of Mercer. From the description given by Mr. Gordon, the variety grown in both instances was evidently not the Dwarf Essex, as it went to seed early. In reference to that sown by himself, Mr. Gordon says: "It was in too great a hurry to form seed to meet my expectations as a forage plant;" and as to that sown by Mr. McCoy, he "had a large flock of turkeys, and they took such good care of the rape that it required no further attention."

In Ohio some rape was grown in 1892 by W. T. Palmer, of Jeromesville. It was sown on a loose sandy soil, plowed in May, on which a heavy crop of mammoth clover had been grown the previous year, and was put in drills 3 feet apart. Mr. Palmer wrote in regard to it, on September 13: "I sowed the rape in June, and now it is about 3 feet high. The leaves have made a near approach between the rows."

In Michigan rape has been grown for one or more seasons by George E. Breck, of Paw Paw; W. Robertson, of Ypsilanti; W. J. Garlock, of Howell; and S. S. Bailey, of East Paris.

Mr. Breck has grown rape for three years. He sows it broadcast about July 10 on land where clover may have failed to catch the previous year. By September 15 it has made a good growth and furnishes an excellent fresh food at a time when it is needed. He pastures sheep on it, the rest of the field being in clover. The sheep prefer the rape to fresh clover. Mr. Breck adds:

> Rape grows and fattens sheep very satisfactorily. It furnishes at least twice as much food per acre for two months as the best of clover, is available at a time when pastures are short, puts sheep into a fine condition for sale or for breeding, and seems to be a natural and healthful food.

Mr. Robertson has grown from 10 to 15 acres of rape yearly from 1888 to 1892—that is to say, for four years. Nearly all of it was sown after a crop of peas and oats, grown together, had been harvested for soiling uses. He has grown it both in drills and broadcast. When sown in drills they were made 28 inches apart, and 2 pounds of seed per acre were used. When sown broadcast 6 pounds were used. He has pastured sheep and in-calf cows and heifers on it. He has always had good crops except in 1892, when no rain fell from July until the end of September. Mr. Robertson states further: "It is a very valuable crop for feeding in October and November, both for cattle and sheep, when pastures are done. I am satisfied that all who grow it once will grow it again."

Mr. Garlock sowed rape in 1892. One of the two kinds, evidently the Dwarf Essex, did remarkably well, while the other variety which blossomed was of but little value. He sowed June 20, but thinks later sowing in moist weather would be better for fall feeding. Mr. Garlock adds: "I never had show sheep push ahead as those did on that feed. I believe wonderful results will follow rape-growing if we can get the genuine seed."

Mr. Bailey grew the Dwarf Essex rape in 1892 only. He sowed 6 pounds of rape seed on July 30, some in drills and some broadcast. Two pounds of seed per acre were sown in the drills. A portion of the land was sandy loam and a portion muck. It made a wonderful growth, some of it reaching the height of 3 feet by October. Corn drilled in at the same time and rye sown simultaneously made no showing in comparison; it literally covered the ground, and the sheep did well upon it. Mr. Bailey adds: "Had I known what I know now, I could as well have put in 25 acres. I desire to thank you for calling the attention of our people to the value of rape as a fodder plant."

In Wisconsin rape was grown by George McKerrow, of Sussex, in 1891 and 1892. It was sown in drills and broadcast, and a large crop was produced both seasons. In 1891 that sown June 15 gave the best crop, but in 1892 the later sowing of July 2 was superior. He has both pastured it and cut and fed it to rams and show sheep in the stable. Mr. McKerrow further mentions: "I consider it a good crop to furnish a good green fattening ration in the fall."

In Illinois rape was grown in 1892 by E. W. Hartley, of Christman. It was sown August 1 and did not prove a success, owing to the excessively dry weather.

In Minnesota rape has been grown by several farmers, including O. O. Monson, of Pomme de Terre; W. W. Kelly, of Lamberton; Fletcher Bros., of Minneapolis; and Thomas Kough, of Mower County. The two first-named gentlemen grew a variety which soon came into blossom, and they do not speak very highly as to its value. Fletcher Bros. grew rape in 1891 and 1892. They say in regard to it: "We will not be without it for our lambs if we can raise it successfully."

Mr. Kough has grown it every year since 1889. Sometimes it was sown on inverted barley stubble after the previous crop had been reaped. In 1890 rape sown broadcast stood over 2 feet high without stretching the leaves. He has sowed it in corn fields at the time the last cultivation is being given the corn, and has found good results. Mr. Kough adds: "I consider one acre of rape worth more than 2 acres of flat and common turnips."

In Georgia A. H. Stoddard, of Savannah, grew rape as an experiment in 1892. He states his experience with it in the following language:

> It grows well here in spring and summer, but is not needed at that time as a grazing plant. I sowed about 3 acres in September and October on a sandy soil with a view to growing winter pasture. It was not a success. It grew slowly.

THE GROWTH OF RAPE.

Owing to the limited experience that we have had in growing rape in America there is doubtless much that is yet to be learned as to the various ways in which it may be grown; but when its growth becomes general this knowledge will speedily increase. Happily we know enough in the meantime to enable us to grow it in fine form where the conditions are suitable.

ADAPTABILITY OF SOILS.

It would probably be correct to say that rape will grow in fine form in any soil that will produce an abundant crop of turnips or Indian corn. It will therefore grow freely in deep, rich, and warm loams, friable in texture. In sandy soils it will grow well, but only on the condition that they are well supplied with suitable plant food, otherwise its growth, though encouraging at the first, will be disappointing in the end. On stiff clays it will not germinate properly in dry weather, and its growth will be slow. On humus soils where vegetable matter abounds it grows with great vigor and luxuriance. Muck swamps, which have been drained, are capable of producing enormous crops. But rape will grow reasonably well on any soil that is moist, friable, and plentifully supplied with plant food in available form.

PLACE IN THE ROTATION.

The place that should be assigned to rape in the rotation will depend on many conditions—the use for which it is grown, the nature of the soil, and the nature of the rotation. Like other hoed crops it should be grown as a cleaning crop when sown in drills, hence it is peculiarly fitting to grow it upon fields which require to be cleaned. It will therefore more commonly come after a grain crop, and ordinarily should be followed by another grain crop sown with grasses and clovers. It may generally be grown with much advantage after a crop of winter rye, which has been pastured or cut at the earing stage for hay, or in the blossoming stage for the silo.

In climates that are suitable, and in seasons that are sufficiently moist, it will also make a good growth after early maturing crops. As rape feeds ravenously on organic matter, it usually grows well on a freshly overturned sod possessed of sufficient moisture to germinate the seed. It may therefore be grown on land which has been pastured in early spring and on overturned clover fields after the first cutting of the season has been removed. As a catch crop it may be sown at any time when opportunity offers, until within, say, eight weeks of the close of the growing season. As a green manure it may also be sown at any time, but for this purpose it is more common to sow it in conjunction with the bare fallow or after some crop of the season has been removed.

PREPARATION OF THE SOIL.

A suitable seed bed for rape calls for fine pulverization, a surface soil free from undecayed vegetable matter, and sufficient moisture to germinate the seed. A fine pulverization is largely dependent on conditions of soil and climate and on the implements of tillage used. The vegetable matter growing on soils to be prepared for a crop of rape should be buried by careful plowing, which should also in some instances be deep, otherwise it will interfere with the ridging of the land when the rape is to be sown in ridged drills. An increase in moisture is secured through the occasional stirring of the soil with the harrow or cultivator sometime previous to the sowing of the seed. When rape follows rye that has been cut for hay, for soiling purposes, or for the silo, the ground should be carefully plowed, using the skimmer at the same time to bury all vegetable matter. It should then be at once rolled to impact the soil and so arrest the ascending ground moisture. The drills should be made with the double mold-board plow, but not so elevated that they will readily dry out. The distances between the drills may vary from 20 to 30 inches. The width from drill to drill may be wider where the land is rich. The same mode of preparing the soil may be followed when the rape is to come immediately after a grain crop that has been allowed to mature. When rape comes after sod land plowed in June or after meadow land plowed late, it would probably be necessary to sow it broadcast or in drills on the level, owing to the difficulty in forming raised drills on such lands.

FERTILIZERS FOR RAPE.

Although rape will grow on many kinds of soil it gives the best results relatively on lands that are rich, and especially on those that are rich in organic matter. When the soil is deficient in plant food the rape grows slowly and lacks that deep green tinge indicative of highest vigor, the plants do not attain sufficient size, and the leaf turns yellow at an early stage, which indicates that nutrition is wanting and that the nutritive processes have been suspended too soon.

Rape responds vigorously to the application of barn-yard manure. As the value of rape is largely in proportion to the development of the stem and leaf, it is not easily injured by being overfed. Nor is there danger that the manure so applied will be wasted, as the rape is a gross feeding plant, and therefore has much power to gather plant food in the soil. The manure should ordinarily be applied in the fresh state and not long before the sowing of the rape, and it should be incorporated with the soil by plowing or cultivating, or by a combination of the two.

Since barn-yard manure is so favorable to the growth of rape we may safely conclude that on average soils complete fertilizers may be used with safety where fertilizers are required. But much, of course, depends on the soil. At this station we have found that nitrate of soda applied at the rate of 200 pounds to the acre gave better results than either superphosphate or muriate of potash, and also better results than when the nitrogenous phosphatic and potassic fertilizers were used in combination. But it would probably be otherwise on average soils. We also obtained excellent results from the application of 200 pounds of salt per acre when applied alone. Superphosphate when used alone has given satisfactory results in many instances. As rape very much resembles the turnip in its habits of growth, it will probably be found that animal phosphate applied in the line of the drill, but not directly in conjunction with the seed, will usually give results that are satisfactory. When grown broadcast the superphosphate may be incorporated with the surface soil by the harrow when preparing the ground for the seed or in covering the same.

SEED AND SOWING.

Three methods of sowing have been adopted, viz, in raised drills, in drills on the level, and broadcast. Which of these methods would be preferable will depend upon the character and condition of the soil and the object sought. The effect of cultivation between the drills is the same with rape as with corn. The growth is stimulated in proportion to the amount of the cultivation given and to its timeliness. It follows, therefore, that when the soil is rich and clean the rape may be sown broadcast. When these conditions do not exist it should be sown in drills. The sowing in raised drills facilitates early and thorough cultivation, but the seed is more certain to germinate when it is sown in drills on the level.

When sown broadcast the work may be done by hand or with some form of grass-seeder. When sowed in raised ridges an ordinary turnip drill will do the work well. It is drawn by one horse and sows two rows at once. For small areas a hand-drill will answer. When sown in drills on the level a grain drill may be made to do the work by using only some of the tubes, and when the drills are suitable a fertilizer may be applied at the same time. The amount of seed to use should be gauged by the condition of the soil and the nature of the weather. The quantity should be increased with the lack of moisture in the soil, with the lack of good tilth, and with the absence of moisture in the atmosphere. When sown broadcast from 3 to 5 pounds of seed per acre may be used, and when in drills from 1 to 2 pounds.

The time for sowing the seed will vary with the object sought and the climate. It may be sown for soiling purposes in May, in the States bordering on Canada and in Canada, and cut or eaten off when it is sufficiently advanced. It will grow up again and may be used a second time in the same manner, but ordinarily the best results are obtained in the latitudes mentioned when sown during the last half of June and the first half of July. When put in earlier, the hot suns of August seem to unduly hasten its maturity, as indicated by slow development and a lightness of tinge in the leaf.

CULTIVATION.

The cultivating of rape should commence as soon as it is well started in the rough leaf, and it should be repeated as frequently as possible until the rape has reached that stage of advancement which will not admit of further cultivation without injury to the plants. This stage is reached when the leaves of the rape have so far extended over the space between the rows that they would be trodden under foot by the horse, or broken off by the whiffletree.

An ordinary cultivator will answer for doing the work, but one that will cut close to the line of the row without covering the plants will best serve the purpose in the earlier stages of the cultivation. The cultivation should be deep at first, and should gradually become shallower as the roots of the plants develop. Level cultivation only is required. It is not usual to give the rape any hand hoeing or thinning, but where some kinds of noxious weeds prevail some hand hoeing along the line of the drills would well repay the outlay. When rape is thinned the plants attain a larger size, but at the price paid for work in this country it has not yet been demonstrated that labor thus expended would prove remunerative.

USES OF RAPE.

It has been mentioned that in Europe rape has long been grown for the pasture which it produces and for the oil which is made from the seed. It is not likely to be grown for the latter purpose on this continent in latitudes which are most favorable to the growth of the Dwarf Essex variety, for this reason, that it does not well survive the winter. It is probable, therefore, that on the northerly portions of the United States and the southerly portions of Canada it will be grown chiefly as a pasture. But experience has taught us, even now, that it may serve a good purpose when sown as a soiling crop, as a green manure, and as a cleaning crop, and further experience may yet reveal other uses to which it may be put.

RAPE AS A PASTURE.

Rape is unrivaled as a pasture for sheep in autumn in those parts of this continent where it can be successfully grown. As a fattening food in the field it is without a rival in point of cheapness or effectiveness. The sheep that pasture upon it do the harvesting in a most effective manner, and with but little cost to the owner; and the manure made from it is distributed over the field which produced the crop, and in a form which is readily available for the plants of the succeeding crops. While rape thus grown and fed does not add fertility to the soil, unless in the plant food which it brings up from the subsoil, it does not detract from the fertility when the sheep which eat it off are inclosed upon it. When rape can be successfully grown as a pasture the necessity for sending sheep and lambs to the market in a lean condition will be removed, and the numbers that may yet be fattened upon it in this country will only be limited probably by the inclination of the farmers and the demands of the market. Four to five millions of acres of arable land would suffice to grow rape enough to fatten all the sheep at present in the United States.

The manner of feeding off the rape when pastured by sheep and lambs is in outline as follows:

> They should be tagged before being turned in upon the rape, or soon after, as they are liable to become purged to some extent at the first. They should not be turned in upon the rape when hungry at any time, as they may so gorge themselves that bloating, followed by death, may ensue. When they have access to an old grass pasture at the same time, the grass eaten by them is usually very effective in preventing scours and other disorders arising from impaired digestion. When the animals are once turned in upon the rape it is not necessary to remove them, unless in time of severe and prolonged storms of rain or sleet. At such times they may be given the protection of sheds when these are available, otherwise the shelter of a grove may prove of some service. After they have fed upon rape from two to two and a half months they will be ready for the market. When it is desired to carry on the lambs into the winter months after the season for pasturing is over, they will go on improving in fine form where the management is judicious. In other words, pasturing on rape is an excellent preparation for winter feeding.
>
> The sheep or lambs should be visited two or three times a day by the shepherd. This may be done on foot when the flocks are small, but when feeding over large areas the aid of a saddle horse should be called in. When sheep get fat and heavy they are somewhat liable to roll over on the back and so perish. They do not require any water when feeding upon rape, but should have access to salt at will.
>
> There is no limit to the numbers that may be put upon one field except its capacity to sustain them. The labor of hurdling does not seem necessary, as the sheep waste very little of the rape. When it has grown strong and rank they feed around the borders. Like an invading army of crawling insects, they make clean work as they go, but when the crop is light and thin they feed in any portion of it.

Cattle may be pastured upon rape, but through treading they destroy and waste it in a considerable degree; because of this it is better to remove them to an adjoining pasture when they have satisfied their wants. The results are usually very satisfactory when they are pastured upon it in the day only, and fed in the stable or shed in the morning before going to the rape pasture. This is an excellent way of making Christmas beef.

It is also more than probable that rape will prove an excellent pasture for swine in conjunction with corn and other food adjuncts, but for this purpose it would require to be eaten off while the weather is still mild.

RAPE AS A SOILING CROP.

Rape has been found useful as a soiling crop, more especially in feeding stock rams and show sheep, milch cows, and swine. It may be fed freely to stock rams and sheep in preparation for the shows with excellent results. It gives tone to the system, puts on flesh rapidly, and precludes the necessity for feeding a heavy grain ration. The amount to be fed is also so completely under the control of the feeder that all danger from excessive eating is completely obviated.

When fed to milch cows the milk flow is generous and free. It should be given to the cow after the milk has been removed. When the cows pasture upon it there is little danger that the milk will be tainted as when turnip tops are fed. Rape may thus be made to furnish a crop for the dairy after all other soiling crops are past their best. Swine are very fond of it and rape will prove of much service as an adjunct to other concentrated foods when the animals are confined to their pens. They have been known to leave grain in some instances to feed upon rape when the latter has been placed before them.

Rape will keep for a long time in early winter in heaps like cocks of hay. When cut and thus put up on the approach of winter it may be drawn and fed as desired, where the snows do not fall too deeply at that season of the year. For soiling purposes it may be found advisable to sow it broadcast to render the cutting process easier.

RAPE AS A CATCH CROP.

Rape is peculiarly adapted for being grown as a catch crop, as, like the turnip, it grows better late rather than early in the season. When a grain crop, therefore, has failed from any cause whatsoever, there is ample time to plow the land and to sow rape upon it. In some seasons it may also be sown after harvest where autumn cultivation is practiced; that is, where it is customary to plow the land lightly after the crop has been reaped. It may then be sown broadcast or in drills as desired. The chief difficulty will arise from the dry weather, which sometimes prevails at such seasons, and which will so far hinder the proper germination of the seed. It may be sown among corn just before the last cultivation which is to be given to the corn. The shade furnished by the corn is favorable to germination. Under some conditions the corn may furnish too much shade, but ordinarily the rape will get a good start before the corn is cut and will then grow vigorously after that season.

Rape may also be sown along with grain in the spring where the ground is not sown with grasses at the same time. It may be sown with the grain drill and may be allowed to fall before the tubes, or it may be sown by hand after the drill and covered by the roller. About 3 pounds of seed per acre may be used. Ordinarily the growth of the rape will not interfere with that of the grain crop, and it will grow vigorously and furnish excellent pasture after the grain has been cut. Sometimes, however, the luxuriant growth of the grain will prove fatal to the rape.

RAPE AS A GREEN MANURE.

As a green manure rape may be made to serve a useful end. Where the bare fallow system is practiced, rye may be sown in the autumn and plowed under in the spring when well grown. This may be immediately followed by the rape, which in turn could be plowed under before sowing a crop of winter wheat. This would be a cheap and effective way of renovating worn soils. A light dressing of nitrate of soda may be given to the rye in the early spring and superphosphate applied along with the rape. The rape could be eaten off before sowing the wheat if it were required for pasture. But where peas will grow a crop of peas will be more effective than a crop of rape.

Rape may be sown for manurial purposes by any of the methods described when speaking of it as a catch crop, but where the facilities are at hand it will probably be more profitable to use it as a pasture.

RAPE AS A CLEANING CROP.

As a cleaning crop rape has but few equals when it is grown in drills, owing to the season of the year at which it must be sown to obtain good yields and to the cultivation which it then requires. When rape is the only crop grown, the ground may be managed as a bare fallow from the preceding autumn until the time of the sowing of the rape. Nearly all kinds of weeds can be sorely harassed in this way, but more especially those which ripen their seeds early. The cultivation which follows while the rape is growing is peculiarly fatal to weeds of a later habit of growth. When rape follows a crop of rye cut green it is also peculiarly helpful in destroying weeds. The rye tends to smother the weeds and is cut before they mature their seeds. The plowing and cultivation which come later still further tend to complete the work of destruction. Growing rape in drills after a grain crop has been removed is also serviceable in destroying weeds, though not quite to the same extent as when it is grown by one or the other of the methods mentioned above.

PRECAUTIONS TO BE OBSERVED IN FEEDING RAPE.

There are some dangers connected with feeding rape which can not be overlooked without serious hazard. It has been mentioned when speaking of rape as a pasture that sheep should not be put upon it when hungry lest they should eat too much. The same is true of cattle. To avoid this danger some feeders put the cattle on the rape only for a short time at the first, and gradually extend these grazing periods until the animals may with reasonable safety be left upon the rape all the time.

With valuable breeding animals the practice would probably be a wise one which would have the sheep turned in upon the rape field after the dew had lifted and taken out of it at night before the falling of the dew. They would not be turned in again upon the rape in the morning until they had previously taken food from some other source.

When rape is fed as a soiling crop this danger may be completely avoided, since the amount to be given is then entirely under the control of the feeder.

Although grain is not usually required by sheep or lambs when feeding on rape, in time of frosts they may with advantage be given a feed of oats early in the morning from day to day, and when this practice has once been commenced, it would probably be unwise to discontinue it. The tendency to certain digestive troubles apparent at such times would thereby be lessened.

The animals feeding upon rape should have access to salt at will. They seem to crave large quantities at such times, and when thus eaten freely it tends to prevent scours and is also in other ways helpful to digestion.

The dangers attendant upon pasturing upon rape are not so great in dry years. In such seasons there may be little or no loss, but in those of an opposite character the losses may be considerable, unless close attention is given to the animals when feeding it off, and it is well to take this into account when undertaking to grow rape for pasture.

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 12.

NOSTRUMS

FOR

INCREASING THE YIELD OF BUTTER.

BY

HARVEY W. WILEY,
CHEMIST OF THE U. S. DEPARTMENT OF AGRICULTURE.

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FARMERS' BULLETINS.

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Farmers' Bulletin No. 1. The What and Why of Agricultural Experiment Stations. (A brief explanation of the object, origin, and development of the stations, their work in Europe and in the United States, and the operations of the Office of Experiment Stations of the Department of Agriculture.) Prepared by the Office of Experiment Stations. Pp. 16. Issued June, 1889.

Farmers' Bulletin No. 2. The Work of the Agricultural Experiment Stations. (Illustrations of station work in the following lines: Better cows for the dairy; fibrin in milk; bacteria in milk, cream, and butter; silos and silage; alfalfa; and field experiments with fertilizers.) Prepared by the Office of Experiment Stations. Pp. 16. Issued June, 1889.

Farmers' Bulletin No. 3. The Culture of the Sugar Beet. (Treats of the climatic conditions, soil, fertilizers, and cultivation required by the sugar beet, cost of growing, time to harvest, and method of siloing; describes briefly the process of beet-sugar manufacture, and gives statistics of sugar production and consumption.) By H. W. Wiley, Chemist of the Department of Agriculture. Pp. 24. Issued March, 1891.

Farmers' Bulletin No. 4. Fungous Diseases of the Grape and their Treatment. (Describes downy mildew, powdery mildew, black rot, and anthracnose of grapes, and gives instructions for their treatment and estimated cost of remedies.) By B. T. Galloway, chief of the Division of Vegetable Pathology. Pp. 12. Issued March, 1891.

Farmers' Bulletin No. 5. Treatment of Smuts of Oats and Wheat. (Describes the smuts of wheat, oats, and barley, the damage they cause, and the various methods of treatment which have been found useful for their prevention.) Prepared by the Division of Vegetable Pathology. Pp. 8. Issued February, 1892.

Farmers' Bulletin No. 6. Tobacco: Instructions for its Cultivation and Curing. Prepared by John M. Estes, special agent. Pp. 8. Issued February, 1892.

Farmers' Bulletin No. 7. Spraying Fruits for Insect Pests and Fungous Diseases, with a Special Consideration of the Subject in its Relation to the Public Health. Prepared by the Divisions of Entomology and Vegetable Pathology. Pp. 20. Issued April, 1892.

Farmers' Bulletin No. 8. Results of Experiments with Inoculation for the Prevention of Hog Cholera. By D. E. Salmon, chief of the Bureau of Animal Industry. Pp. 40. Issued May, 1892.

Farmers' Bulletin No. 9. Milk Fermentations and their Relations to Dairying. Prepared in the Office of Experiment Stations. Pp. 24. Issued July, 1892.

Farmers' Bulletin No. 10. The Russian Thistle and other Troublesome Weeds in the Wheat Region of Minnesota and North and South Dakota. Pp. 16. Issued April, 1893.

Farmers' Bulletin No. 11. The Rape Plant: Its History, Culture, and Uses. Pp. 20. Issued June, 1893.

NOSTRUMS FOR INCREASING THE YIELD OF BUTTER.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Chemistry,
Washington, D. C., May 11, 1893.

Sir: I beg to submit for your inspection the manuscript of Farmers' Bulletin No. 12, on nostrums for increasing the yield of butter.

Respectfully,

H. W. Wiley,
Chemist.

Hon. J. Sterling Morton,
Secretary of Agriculture.

GILT-EDGE BUTTER COMPOUND.

For several years the farmers of the country have been tempted to invest in various secret nostrums which it was claimed would increase the yield of butter. In the Annual Report of the Department for 1891 an analysis of a sample of this kind and a description of its effect in increasing the apparent yield of butter were given. The report was as follows:

> Mr. H. J. Fish, superintendent of the Producers' Dairy Company, 324 B street southwest, Washington, D. C., brought to me a sample of genuine butter, together with a sample of artificial butter, prepared by taking equal parts, by weight, of the genuine butter and milk and churning them together with the addition of a small quantity of the substance known as "gilt-edge butter compound," from the Planet Manufacturing Company, of Wichita, Kans. The directions for the use of this compound are to take a pint of fresh unskimmed milk and as much of the compound as you can heap on a silver 10-cent piece, and thoroughly mix the compound and milk together in the churn with as much salt as is necessary to salt 1 pound of butter. Add to this 1 pound of soft butter, and churn until the whole mass has come to butter, when you will have 2 pounds of butter and no milk. It is directed that the genuine butter should not be melted but made very soft and pliable, so that the churn-dasher will easily go through it. The milk should be warmed to the temperature at which it is taken from the cow. The churn should always be scalded or warmed sufficiently to prevent chilling the milk, plenty of salt added, and butter color, if used, before churning. It is particularly enjoined that the butter should not be worked, but should be made into rolls and put into jars and set away in a cool place to harden.

The sample of genuine dairy butter which was furnished with the compound was found to contain—

	Per cent.
Water	15.92
Butter fat	80.53
Ash	.38
Curd and undetermined	3.17

This represents a fair sample of butter, with the exception that the water and curd are a little higher than the average. In the premium butters obtained at the Chicago Dairy Show in 1889, the percentage of moisture varied in ten samples from 8.69 per cent to 11.86 per cent.

The artificial butter prepared from the above by the Producers' Dairy Company was subjected to analysis, and the following numbers were obtained:

	Per cent.
Water	49.55
Butter fat	45.45
Ash	1.34
Curd and undetermined	3.66

It would appear from the above that the artificial butter had been made by churning the pure butter with a very dilute milk.

There was no doubt at all that the gilt-edge butter compound would do what was claimed for it, inasmuch as Mr. Fish had made the butter himself according to the directions.

The compound was also submitted to a practical test in the laboratory of this Department, and it was found that with 1 pound of butter, 1 pint of milk, and about 1 gram of the butter compound, 2 pounds of material could easily be made which resembled very closely a first-class article of butter, except that it was considerably softer.

It was at once suspected that the compound contained some emulsifying substance, either of a mineral nature or some organic ferment. On subjecting the butter compound to analysis it was found to contain 70.48 per cent of anhydrous sodium sulphate and 29.52 per cent of organic matter. This organic matter responded perfectly to the test for pepsin, and part of it was undoubtedly pepsin; whether a pure pepsin or a crude form was not determined. Having established the fact that this was pepsin, experiments were made with pepsin and other digestive ferments, viz, pancreatin and trypsin. These bodies act as pepsin, and produce an emulsion which enables butter to incorporate an equal weight of milk in its substance without materially altering its appearance. The experiments were also tried with rennet, and it was found to act in the same way; whence it may be concluded that all the digestive ferments, when beaten up with milk and butter in the manner indicated, will produce an emulsion apparently causing the milk to entirely disappear.

The gilt-edge butter compound is colored pink, with some organic coloring matter, in order to obscure its real nature. The anhydrous sodium sulphate seems to be added simply as a carrying material, and it is not supposed to produce any active effect in the emulsifying process; in fact, pepsin, pancreatin, trypsin, and rennet used without anhydrous sodium sulphate produce exactly the same emulsifying effect as the gilt-edge butter compound.

By this simple device the unprincipled dealer could easily impose upon his customers, furnishing them with an article of butter containing only half of the portion of that substance without greatly diminishing its price. The keeping properties, of course, of the emulsified butter would not be very great, but for rapid home consumption this would not be noticed.

BLACK PEPSIN.

During the year 1892 the Department received many communications relating to the methods of increasing the yield of butter—nearly all the correspondents speaking of the agent employed as "black pepsin." Evidently the success of those engaged in the "gilt-edge butter compound" business was such as to excite the envy and emulation of other unscrupulous persons. Advertisements appeared in agricultural and other newspapers and many unwary and uninformed persons became victims of the fraud. The continued success of the fraudulent compound was of such magnitude as to warrant another notice of it in the Annual Report of the Department for 1892. This report contains the following information:

> In the Report for 1891 was published a description of a preparation designed to increase the yield of butter. This preparation was sold at a high price and had the power of causing the incorporation of the casein, milk sugar, and other constituents of the milk with the butter fat. This was effected by producing a kind of an emulsion by which these bodies were held in suspension. The apparent result of the process was to double the yield of butter. It was pointed out at the time that this substance was pepsin and that the apparent yield was in reality a delusion, as, of course, there is no method by which the actual content of butter fat in milk can be increased after the milk leaves the cow.
>
> During the present year the Department has received numerous inquiries concerning the substance known and sold as black pepsin, which is used for the purpose described above. In reply to these inquiries the information has been of a uniform character, viz, that this substance has essentially the properties ascribed to it, but that its use in all cases must be regarded as a fraud and hence avoided.
>
> One sample of the black pepsin above referred to has been examined by the Department and found to consist essentially of a mixture of crude pepsin with sugar. It is hoped that farmers will not be deceived by the claims of persons desiring to sell this compound, inasmuch as butter made in this way will soon spoil and is practically not butter but simply an incorporation of butter with about an equal weight of other substances. The sale of such butter is also practically an adulteration of a food product and should be prohibited by law.

In spite of the warnings given in the above reports of the Department and by the dairy commissions and agricultural experiment stations of many of the States, a brisk and apparently increasing trade has been kept up in these substances greatly to the detriment of those innocently purchasing the nostrums and to the consumer of the product—a product not butter, but a mixture of butter fat with water, casein, milk, sugar, and other constituents of milk. Such a product soon suffers a separation of its constituents, and is exposed to the decay of its nitrogenous components and a speedy rancidity of its fatty ingredients. The magnitude of these fraudulent practices and the extent to which they have spread throughout the country have been revealed in quite a startling manner by replies to a circular asking for information on this subject sent to boards of health, members of dairy and pharmaceutical associations, and city officers throughout the country.

The numerous replies to this circular which have been received have been referred to Mr. A. J. Wedderburn, special agent of the Department for the investigation of the general aspects of food adulteration. As a result of his study of these replies Mr. Wedderburn has prepared the following preliminary report:

REPORT OF A. J. WEDDERBURN ON BLACK PEPSIN IN BUTTER-MAKING.

The investigation recently undertaken of the extent and character of food and drug adulteration has revealed two new and extensive frauds, and feeling that I have secured evidence enough from reliable sources to justify the publication of the results of the inquiry, I submit the accompanying advance report and take the liberty of suggesting that the same be at once given to the public to offset as far as possible the ill effects of the proposed expenditure of $125,000 in advertising the articles prepared by the firm offering these goods for consumption by the people.

Circulars issued by the Division of Chemistry of the U. S. Department of Agriculture, April 20, making inquiries as to the "extent and character of food and drug adulteration," have already brought replies from nearly every section of the country, many of which give trustworthy information concerning the various adulterations practiced and evincing a strong interest in the subject on the part of the writers.

The query as to what was known about "black pepsin in (so-called) butter-making" has brought forth more replies than any other, and the information obtained is so reliable in its character and of such importance that it is deemed proper to present without delay the following statement:

(1) Of over 2,500 letters received from all parts of the United States only two indorse the use of black pepsin.

(2) While many of the replies state that nothing is known of the article, numerous correspondents say they have had inquiries for it. A large number have it in stock and are selling it. A majority unite in pronouncing it a fraud, and one writer says he has written the manufacturer that if any more of his printed matter is sent to him he will forward it to the postal authorities to ascertain whether the sender is not liable for prosecution for using the mails for fraudulent purposes.

A reputable chemist sends an analysis of the butter made with this solidifying adjunct, and it shows only 63 per cent of butter fat. Butter should not contain less than 85 per cent.

The advertisement above alluded to is printed on a postal card, and states that $125,000 will be spent this season in advertising black pepsin and two other articles, one of which is a preservative powder for fruits and vegetables, and, as the correspondent states, nothing more or less than salicylic acid, an article which in unskilled hands is most dangerous to health and life. The black pepsin is retailed at $2.50 a box of 2 ounces and wholesaled at $2. The preservative powder is sold at retail for $1.25 a box and at wholesale for $10 per dozen. For obvious reasons the name and address of the vendor are withheld.

An analysis of the so-called "black pepsin" made for the Evening News, Detroit Mich., and published in that paper April 1, 1893, shows the following result:

	Per cent.
Salt	83
Annatto	15
Rennet and organic matter	2

The value of the 2-ounce box sold at retail for $2.50 is about 3 cents.

Extensive advertising is undoubtedly creating a large inquiry for these products, though their sale and use are fraudulent. The milk solids are curdled and the sugar and casein "turned to butter," as the advertiser expresses it. The use of black pepsin certainly violates the spirit if not the letter of the oleomargarine law, and dairymen who insist that oleomargarine and other imitations of butter shall be properly branded of necessity must oppose the use of any chemical that certainly perpetrates as great a fraud on honest butter as any other imitation.

There are several other preparations sold in this country and Canada, which have not yet been fully investigated. Believing that these products are being advertised by the press, sold and used from ignorance of their true character and value, it is deemed proper to submit this statement in advance of the regular bulletin which is now in process of preparation and can not be completed for some months to come.

The letters upon which this statement is based have been received from the following States: Alabama, California, Delaware, Florida, Georgia, Indiana, Illinois, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Missouri, Michigan, Nebraska, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Utah, Vermont, Virginia, Washington, and Wisconsin.

It seems strange that such a palpable fraud should continue to be practiced after its repeated exposures by this Department and by leading agricultural papers.

METHODS OF ADVERTISING BLACK PEPSIN.

In respect of the method of advertising black pepsin, the direct way of sending postal cards and circulars to the farmers seems to be the one chiefly followed.

A vigorous attempt has also been made to interest the druggists of the country in the sale of this article, as well as others of similar character. Following is a copy of a postal card which has presumably been sent to the drug trade in general. It was addressed to Otto Bauchfuss & Co., Cincinnati, Ohio. The card was mailed at New Concord, Ohio, April, 1893:

PRICES FOR 1893.

We will expend in 1893 $125,000 advertising these three specialties. Place these on your lists, as you will certainly receive orders.

Black pepsin.—A powder prepared expressly for increasing the yield of butter and cheese. Each box will make 500 pounds of butter. Retails $2.50 per box, $24 per dozen. Ten per cent off to wholesale and jobbing trade. Three per cent off for cash in ten days.

Electrofied silver.—A metal for plating articles usually plated with silver. Can be used without any battery and requires no experience to apply it. You can plate a dozen spoons in fifteen minutes, and guarantee them for ten years. Each package will do $350 worth of plating. Retail price, $7.50 per package, $75 per dozen. Ten per cent off to wholesale and jobbing trade. Three per cent off for cash in ten days.

Compound extract of salyx.—A powder for preserving fruits and vegetables. Each box preserves 25 gallons of fruit. Retails at $1.25 per box; $10 per dozen. Ten per cent off to wholesale and jobbing trade. Three off for cash in ten days.

U. S. SALYX CO.,
New Concord, Ohio, Sole Proprietors.

The electrofied silver mentioned in the above card is without doubt some mercurial amalgam, and is a striking example of how freely in this country the vendor of poisonous articles is allowed to bring them to the notice of the trade. "The compound extract of salyx" is the gorgeous title under which the modest salicylic acid is made to masquerade.

The rigid enforcement of the postal laws prohibiting the use of the mails for fraudulent purposes would exclude these postal cards from circulation. The circular and postal-card advertisements are nearly the sole resources of the Salyx Company, since few newspapers will admit to their columns the advertisements of such barefaced swindlers.

WHAT IS BLACK PEPSIN?

So complete is the fraudulent nature of this material that it has been doubted by some eminent chemists whether the supposed active material in it is of any value whatever. This phase of the case is thoroughly set forth in the following extract from a letter received from Prof. H. A. Weber, of Columbus, Ohio:

> * * * Black pepsin is made and sold by a man named Bane, under the style of "U. S. Salyx Co., New Concord, Ohio." According to Prof. Kedzie, it consists of salt and coloring matter. It is sold for making 2 pounds of butter out of 1 pound of butter and 1 pound of milk. It is also claimed to be patented, and county rights are being sold in this State. But as the assignments which have come to my notice do not even contain the number of a patent, it is reasonable to assume that this claim is not true. Many people have been induced to buy the fraud, in hope of making money out of it. Numerous inquiries have come to the office of our dairy and food commission as to whether this butter could be sold under our laws as unadulterated. But as it is one-half butter and one-half milk, it could of course not be allowed to be sold.
>
> It is true that a pound of soft butter and a pound of milk slightly warmed, churned, or shaken together will unite to a solid mass weighing 2 pounds. But the black pepsin plays no part in this operation, as it can be accomplished just as well without as with it.
>
> About three years ago a party in Marion, Ohio, sold a preparation of this kind for the same purpose for $1 a box, containing about an ounce of a powder. He sent the powder through the mail to purchasers all over the country. A postal detective sent me a box for analysis. It consisted of alum, bicarbonate of soda, and turmeric. The circular accompanying the box gave instructions for making butter out of equal parts of butter and milk, and for 2 pounds it was only necessary to add of the powder what would be held on the point of a penknife. I told the detective that the powder was a fraud, as the same thing could be accomplished without the addition of the powder. The party was arrested, tried before the United States court at Toledo, Ohio, convicted and sent to the penitentiary for using the mail for fraudulent purposes. This black pepsin is just as great a fraud.
>
> If you wish to make the experiment, put a pound of soft butter into a wide-necked bottle, add a pint of lukewarm milk and shake for a moment, and you will see how readily the milk and butter will emulsify. * * *

From our correspondents we learn that many other nostrums are in use besides those which we have mentioned in this report and the analyses of which follow. All of these preparations make the same claim for increasing the yield of butter. Among others, one correspondent says that a mixture of alum, pepsin, and yolk of egg has been employed, which with 1 pound of butter and 1 quart of milk will make 2 pounds of richly colored butter.

BUTTER MADE WITH THE COMPOUND.

It is not probable that butter made in any of the ways mentioned or by any of the means employed can secure a permanent hold in the market. Its tendency to separation, decomposition, and rancidity would be so great as to condemn it for general use. Nevertheless such butters are found in our markets, as the following letter from Dr. Henry Leffmann, 715 Walnut street, Philadelphia, will show:

> I send you by this mail a small sample of butter such as is occasionally sold in this city, principally in the district mostly occupied by very poor people; in fact, the "slum" district. This butter, when first bought, is pale and spongy. The sample has dried somewhat, but when I first got it it contained approximately 40 per cent of water. Several samples were brought in, and I am not sure that the portion I send you is from that which I analyzed, but they are evidently of the same general origin. I do not know how the butter is prepared, but it is sold at about half the price per pound lump that ordinary butter brings. In samples purchased about a year ago I failed to find any fat other than butter fat, but I have not tested the recent samples for this determination. I send the sample to you, because it may be of some interest as one of the adulterations of dairy products, and I will be pleased to learn of safe arrival.

The sample of butter gave on analysis the following data:

	Per cent.
Water	31.93
Fat	67.30
Curd	.63
Ash (salt)	.15

The butter fat contained 4.86 per cent volatile acids and gave a Reichert number of 27.62. It was therefore pure butter fat. The remarkable features of this butter are its excessive water content and its extremely low percentage of curd and salt. It appears to have been made originally by emulsifying a fair quality of butter with a large quantity of water. It could not have been emulsified with milk on account of the low content of curd.

A simple test can be easily applied by anyone to distinguish one of these so-called butters from the genuine article. On melting a genuine article of butter the amount of water which will separate on the top of the melted mass is very small and should not exceed 12 per cent in volume of the whole material. By placing a little of the suspected butter in an ordinary test tube and melting it at a gentle temperature and comparing the same with a sample of genuine butter the difference in the amount of the material not butter fat will at once be noticed. In the adulterated article almost half of the whole volume will be a mixture of water, curd, and other materials, while with the genuine article of butter the fat will separate in a clear, limpid mass, and a small amount of water and a little curd only will appear at the top. It is not difficult for any person, no matter how unskilled in manipulation, to distinguish the fraudulent from the genuine butter by the test described.

ANALYSES OF BUTTER COMPOUNDS.

An attempt was made to secure samples of all the various nostrums which are sold for the purpose of fraudulent use in butter-making, and a description of the samples which have been received, with the results of the analyses, are given below:

Serial No. 11255.—Purchased of Ott & Nicoud's pharmacy, northwest corner Fifth and Pine streets, Philadelphia, Pa. Small sample, for which 38 cents in stamps were paid. The substance was a brick-red powder, mixed with a white crystalline powder containing an abundance of the characteristic starch grains and fragments of the seed coat of some leguminous seed, probably the pea or bean. The sample was accompanied by the printed directions for making butter with black pepsin which follow:

"Let the cream or milk stand until sour and thick, as you would for ordinary churning. Then churn at a temperature of from 65° to 70° until the butter begins to gather, then stop churning. Now take 4 pounds of butter for each gallon you are churning, and heat it to about 100°; add to the melted butter 1 teaspoonful of black pepsin to each 4 pounds melted butter. (The directions on each box of black pepsin tell how to dissolve it.) Three gallons of cream would require 12 pounds of butter melted and 3 teaspoonfuls of dissolved black pepsin; after you have added the black pepsin to the melted butter, while still warm, pour it into the churn and churn until the butter is like thick cream; then draw off the buttermilk, and pour in on the warm butter enough strong brine to cool and harden the butter; make the brine of salt and cold water—the colder the better; churn the butter in this brine a few minutes till it breaks in lumps as butter usually does, then take up, work, and salt to taste. After deducting the weight of the melted butter you should have more than twice the butter you would in the usual way of churning, and it requires much less time to churn. The melted butter causes the black pepsin to assimilate with the cream, and unites in the form of butter all the cheese, sugar, and butter that milk contains. You can use strong butter or butter that is off in color for melting, as the heating and churning in fresh buttermilk will make the strong butter fresh, sweet, and uniform in color. The more milk the cream contains, the more butter you can make; so do not skim the cream close, but leave in plenty milk—the more the better. Remember this: Leave in plenty milk—the more the better.

"*Copyrighted in the United States of America, according to act of Congress, in 1892, by Cloud Harlin, of Toronto, Canada.*"

Serial No. 11257.—A small sample of black pepsin from C. P. Benson, druggist, Charlottesville, Va. The sample consisted of one-eighth ounce, and the price paid was 40 cents. It had the same physical and microscopical composition as No. 11255.

Serial No. 11258.—Bought of Edward N. Cole, druggist, Kokomo, Ind. One box of black pepsin, of which the price was $2.50. The directions for making butter are the same as above. Printed on the box is a statement that "the contents of this box are sufficient for 500 pounds of butter." Examined by the microscope the sample disclosed black masses of granular matter which contained soluble starch but no visible unchanged starch grains. It was a mixture of reddish-brown particles of armatto, white crystalline particles and blackish particles, giving the whole a grayish appearance. It was evidently quite a different compound from the two mentioned above.

Serial No. 11259.—Bought of R. H. Thomas, publisher of Farmers' Friend, Mechanicsburg, Pa. The directions for use were the same as given above. The microscopical and physical appearance of the sample was the same as for No. 11255. Price of box, $2.50.

Serial No. 11260.—Bought of West & Jenny, Boston, Mass. It contained the same directions as printed above and resembled in every respect No. 11255.

Serial No. 11263.—Gilt-edge butter compound. Bought of C. W. Smart, druggist, Allegheny, Pa. Mr. Smart writes that "the sample of powder inclosed for examination is being pushed very extensively in this locality at present. I have been asked to handle it, also had calls for it and black pepsin, neither of which I have in stock. The calls for black pepsin come from the farming district out the Pittsburg and Western Railroad." The circular describing its properties and use, which accompanied the sample, is given on page 12, under No. 11665.

On microscopic examination it was found to be a pinkish-colored powder, only partially soluble in water. The coloring matter is insoluble in ether and soluble in water, properties which are directly opposite to those of annatto. The amount of the sample was so small as to render a satisfactory determination of the coloring matter impracticable.

The insoluble matter is composed of wheat or rye starch and granular matter, the nature of which was not determined. The sample did not appear to contain any pepsin or rennet, or organic ferment capable of coagulating milk. The mineral matter which it contained was sodium sulphate, of which the quantity found was 50.18 (anhydrous salt). From the above it is seen that this sample of gilt-edge butter compound is quite different from that which was originally analyzed in the Division of Chemistry.

Serial No. 11264.—Bought of the Standard Drug Company, Cincinnati, Ohio. Price of box, $2.50. It contained the same directions for use as given above. The sample resembles in every respect No. 11255.

Serial No. 11265.—Sent by N. W. Cady, secretary board of health, Logansport, Ind. He says: "I send you herewith a sample of 'preservaline' for analysis by the Chemical Department. There is no bill for the stuff, and I will feel amply repaid if you will let me know the results of the examination. The circular which I send with it directs its use in the proportion of 1 to 70, so you may judge of the dangerous results likely to attend the use of such excessive quantities of a substance which is most likely poisonous."

The examination showed that it was a white powder soluble in water. On heating it fuses to a colorless glass without blackening, showing the absence of any considerable portion of organic matter. It seems to be almost exclusively composed of borax. A sample of "preservaline," which was analyzed for the Evening News, of Flint, Mich., contained: common salt, 45.30 per cent; borax, 44.18 per cent, and water, 7.80 per cent. It is used largely for preserving meat, and according to Mr. B. Terne it contains, when used for this purpose, rosanilin, intended to give meat preserved with it the red color supposed to be peculiar to that pickled with potassium nitrate. This red color is omitted when the substance is intended to be used for preserving butter or milk.

Serial No. 11267.—The box had been opened and some of the material used. Presented by W. M. Hilleary, lecturer State Grange, Turner, Oregon. The sample was similar to No. 11258 in all of its physical and microscopical characteristics, except that it contained a little more annatto than that sample.

Serial No. 11268.—The sample was purchased from parties furnishing it to creameries at Owosso and Vernon, Mich., who use it in churning over old rancid butter for making fresh creamery butter out of it. It was sent by S. J. Wilson, secretary of the Michigan Dairy Association, Flint, Mich.

It is a white powder only partially soluble in water. The insoluble portion is composed of wheat or rye starch and some undetermined granular matter. The sample does not have any power of coagulating milk and therefore probably contains no organic ferment. The soluble portion is composed chiefly of sodium sulphate and potassium nitrate. It contained of the latter substance 47.80 per cent. It also contained 11.13 per cent of albuminoid substances. It is essentially a mixture of potassium nitrate with some sodium sulphate and a large quantity of wheat or rye flour.

Serial No. 11269.—Bought from Morrisson, Plummer & Co., Chicago, Ill. Price, $2. The sample resembles in every respect No. 11255.

Serial No. 11270.—Compound extract of salyx. Purchased from Morrisson, Plummer & Co., Chicago, Ill. Price 85 cents. The substance is used for preserving milk and butter. It is a white, homogeneous, distinctly crystalline powder, without any appreciable ash. By proper tests it was found that it was nothing but salicylic acid.

Serial No. 11665.—Gilt-edge butter compound. Obtained from the New York State dairy commissioner, who secured it from the Eureka Manufacturing Company, office, 444 Broadway; manufactory, 10 Lancaster street, Albany, N. Y. The letter of the company, accompanying the sample, was as follows:

"We send you a small sample of our butter compound (enough to make several pounds). In making tests, you need not use a pound of butter and a pint of milk as directions say, but use, say, one-quarter pound butter and one-quarter pint milk and compound in proportion. Use a quart bowl and a spoon for a churn, and the result will be the same with less expense, and much easier tested. Beat the mixture, as you would beat an egg, into a froth, and if the ingredients are all of the right temperature it will come in two minutes. Follow the directions closely and you can not fail of having success."

The chemist of the New York State dairy commission, R. D. Clark, M. D., in forwarding the sample, says: "We have known that 'butter compound' has been advertised from 444 Broadway, Albany, N. Y., for several months. But as we have no jurisdiction over the compound we have paid no attention to that, except to use it as directed in order to determine the nature of the product. It is the product on the market that we want to find, which, as I stated in a previous letter, we have been unable to do as yet. * * * Mr. Talmage, a party who makes the stuff, informs me that it is composed of two parts of bicarbonate of soda and one part of sugar of milk. It originally contained chrome yellow, but that is now left out."

The sample which we received was a white powder entirely soluble in water. A qualitative examination showed the mineral matter present to be bicarbonate of soda, with a trace of sulphate and chlorid, probably as impurities. The bicarbonate of soda is mixed with an organic substance which reduces Fehling's solution very powerfully, and by other tests is shown to be milk sugar. The sample does not coagulate milk and therefore does not seem to contain any pepsin, rennet, or other organic ferment.

BUTTER-MAKING BY A NEW PROCESS.

An attempt was also made to obtain more definite information in regard to a new process of making butter, which is described in the following circular:

NEW PROCESS OF MAKING BUTTER FROM MILK.

The butter industry of the United States is of immense importance. In round numbers, there are from $5,000,000 to $15,000,000 worth sold annually in each State. In 1890 Illinois produced 95,000,000 pounds, worth about $20,000,000; Wisconsin, 45,000,000 pounds, worth $9,000,000; Iowa, 100,000,000 pounds, worth $21,000,000; Minnesota, 42,000,000 pounds, worth $8,000,000; Michigan, 40,000,000 pounds, worth $7,500,000.

The capital of all the national (and registered) banks in 1885 was $640,000,000, while the assessed value of the cows of the country was $700,000,000.

It is estimated that there were 1,200,000,000 pounds of butter manufactured in the United States during 1890. The annual dairy product exceeds in value that of the lumber, wheat, and iron interests combined.

It is apparent that any improvement which materially increases the butter product must be of immense value. Recently it has been discovered that the amount of butter produced from a given quantity of milk can be more than doubled while the article so produced is of superior value. Many trials and tests have been made to determine the correctness of the inventor's claims. For accuracy, comprehensiveness, understanding, and unimpeachable veracity none are entitled to more respect and confidence than the tests made at the State experimental farm of Minnesota by Prof. Edward D. Porter, superintendent. These tests (or trials) extended through a period of seven months, and are graphically stated by the professor, who says:

"Butter, as commonly made in the best creameries, is obtained in the maximum ratio of 4 pounds to every 100 pounds of milk, this proportion decreasing according to the quality of the milk and the manner of churning. Every 100 pounds of milk contain in round numbers 87 pounds of water, 4 pounds each of butter, casein, and sugar, and a pound of salt and other solids. By the common process of churning we get only the butter and lose the casein and sugar; in making cream cheese we get the butter and casein and lose the sugar. This new process gets all these elements, and consequently makes 12 pounds of butter where otherwise but 4 pounds are obtained.

"My scales told me that the claims of the inventor were thus far substantiated, for the work was done under my own eye. The remaining questions were as to the quality of the butter in taste and purity. I have proved the butter pure, for no chemicals are used in it other than those, such as salt and coloring matter, which are used by all creameries. My customers have, with myself, proved the taste, finding it sweet and flavored like the best of creamery butter, and Wesley Neill found it sells equally with his best brands that are stock favorites.

"I am satisfied that the new process will revolutionize the butter industry wherever a dairy is large enough to warrant its use. The process is entirely mechanical. It consists in a more perfect churning and regulation of temperature."

It should be said by way of explanation that this new process butter contains all of the muscle and fat-producing elements of milk. What mother attempts to raise an infant on butter or cheese alone?

Milk in its totality represents a complete and typical food, in which all the constituents necessary for maintaining life and growth of the body are present; while the butter element alone, *i. e.*, creamery butter, does not contain this typical food, and is in no proper sense a muscle or health builder.

This new process butter, upon the contrary, is a typical food, by reason of its containing the casein and sugar of the milk. (It is casein and sugar that gives us healthy children.) Casein is the chief proteid in milk, in its character closely related to alkali albuminates, containing also a large amount of phosphorus, on account of which it is closely allied to nucleo-albumin, being in the truest and fullest sense a nerve and muscle building food.

Thus it may be fairly said that this new process butter is of far superior value to our best creamery product. If we can get double the quantity from the same milk, and if the butter so obtained is of superior value, it may be said in all fairness that the new process is valuable.

Referring to the amount made by the States cited above, it will be seen that we add 270,000,000 pounds annually to their butter product and that, too, without the addition of a single cow. An interest so immense, an industry so honorable and valuable to the community is not often found.

Nothing calculated to restore health and build up American manhood equal in promise and extent to this new process of butter-making has occurred in the past quarter of a century.

From the Waukegan Record, Waukegan, Ill.:

"The inventor, after long and patient study and experiments, patented a new process for making butter, and has spent a week showing the practical operation of the process on the well-known dairy farm of L. N. Brown, of Gurnee. Brown says, after repeated trials of over seventy churnings, he has made from 14 to 16 pounds of pure, sweet butter, equal in every respect to the best creamery, from 100 pounds of milk, while by the old process the average is about 4 pounds to the 100."

Better butter and more of it is the watchword of the day.

Prof. Porter says: "I saw the result yesterday of an analysis at the State University, and the butter was pronounced the purest they had ever seen. It will keep much longer than any other butter. It contains no cheese, but casein, from which cheese is made, is turned into butter. It is just as good and more nutritious than the best creamery butter.

Creameries can use this process without additional expense, and can use any style of churn.

Inquiries concerning this new industry should be directed to

J. D. Hollister,
133 and 135 Adams street, Chicago, Ill.

Some small samples of butter were sent which were said to have been made by this process, but they reached us in such poor condition as to afford no accurate idea of the character of the product secured.

COMPOSITION OF BUTTER-MAKING COMPOUNDS.

The following are the results of the chemical examination of the samples received in so far as they have not been described above:

Serial number.	Moisture.	Ether soluble matter (mostly annatto).	Nitrogenous matter (N × 6.25).	Nonnitrogenous organic matter insoluble in ether.	Ash.			Chlorin.	Common salt.	Sulphuric acid.	Calculated as sodium sulphate.
					Soluble in water.	Insoluble in water.	Total.				
11255	3.03	3.00	5.63	25.59	61.64	1.11	62.75	....	....	....	....
*11257	....	....	....	....	57.98	1.28	59.26	....	....	....	....
11258	1.21	.97	4.88	11.96	80.37	.61	80.98	....	....	....	....
11259	2.96	3.20	5.63	25.58	61.50	1.13	62.63	36.81	60.67	.39	1.62
11260	3.18	3.17	5.79	27.55	59.10	1.21	60.31	35.62	58.72	.32	1.29
11264	3.47	3.22	5.54	26.72	59.74	1.31	61.05	36.18	59.64	.42	1.67
11267	1.87	1.38	4.47	14.51	76.96	.81	77.77	46.54	76.71	.26	.81
11269	2.95	3.17	5.78	24.72	62.07	1.31	63.38	36.35	59.93	.37	1.50

* Sample insufficient in amount for complete examination.

In regard to the starchy matters which were contained in the samples of black pepsin, they may have been added as a diluent of the annatto, or as a drying material in the manufacture of the pepsin or rennet employed in the preparation of these bodies.

Annatto was the coloring matter found in each case, except that of the pink powder mentioned. The coloring matter of the annatto is readily soluble in ether, leaving a dirty, brownish residue. The soluble ash was in each case composed of sodium chlorid, with the exception of the case of the nitrate of potash and sodium sulphate mentioned. There was also a little sodium sulphate present in most cases and in one instance a considerable quantity of sulphate of magnesia. It is probable that these may have been accidental impurities of the common salt employed.

The property of coagulating milk was chosen as the most definite means of detecting the presence of rennet or pepsin, or other organic ferments of the digestive series, in the several preparations examined. Inasmuch as sodium chlorid and other organic salts have also the power of coagulating milk, comparative experiments were necessary to exclude this possible source of error. In the case of sodium chlorid relatively large quantities of the salt and a considerable amount of time are necessary to produce coagulation in any degree that at all resembles that produced by an organic ferment. In the execution of the experiment 5 grams of the sample were placed in a small beaker and rubbed to a homogeneous paste with 5 cc of water. After allowing some time for the complete solution of the pepsin, 50 cc of milk, previously warmed to 40° C., were stirred in and the beaker placed in a water bath of which the thermometer registered 40° C., a little above blood heat. After five or ten minutes the milk was thoroughly coagulated in each case of the black pepsin compound, showing the presence of a small amount of pepsin or rennet. Milk in comparative experiments with 4 grams of sodium chlorid remained unchanged after four hours at the same temperature.

It is curious to observe that there are two distinct types of the black pepsin found, as indicated by the above analyses. Serial Nos. 11255, 11257, 11259, 11260, 11264, and 11269 evidently all belong to the same general type, as their composition is as nearly the same as could be expected, owing to the difficulty of effecting a complete mixture of the materials employed. On the other hand, serial Nos. 11258 and 11267 represent a different type, containing about 20 per cent more of organic matter than the type first mentioned. In fact, it seems to make but little difference about the type of the material employed, inasmuch as any of these preparations containing a small amount of rennet or pepsin can be used for making the imitation butter desired. Evidently, however, two distinct firms are engaged in the manufacture of the material.

The actual value of a box of the so-called black pepsin is only a few cents, and therefore the enormous profits which are made in its manufacture and sale at $2.50 a box can be well imagined.

It is not believed that any further exposition of this barefaced fraud is necessary. We have made an attempt to obtain samples of all the various compounds which are sold for producing the effects described. There are many of them, however, which we were not able to get. Farmers can rest assured that any substance which is presented to them for the purpose of increasing the yield of butter above that of the normal belongs to some such class of fraud as has been exposed in this bulletin.

The proper way for increasing the yield of butter is to secure a breed of cows giving a milk with a high content of butter fat, giving the animals proper nourishment, and keeping them in a clean and healthy condition. The proper treatment of a herd of cows, together with neatness in the dairy, not only will give an increased yield of butter, but will also enable the producer of it to get an increased price.

The best method of making a good and sweet butter in large quantity is careful selection of cows and careful feeding and care in the dairy. The proper attention to neatness and the sterilization of the vessels used about the dairy will secure the growth of a ferment which properly ripens the cream and excludes other ferments, which produce all kinds of injurious changes in the milk. All vessels used in the dairy should be subjected every day for some time to the temperature of boiling water, to absolutely exclude all putrescent bodies and fermentative processes from the dairy, save those which are necessary to the normal ripening of the cream. The farmer who attends to these details will have no occasion to invest his money in fraudulent nostrums for increasing the product of his dairy and the magnitude of his profits.

The dairy industry of the United States is already one of great importance in agriculture and is rapidly increasing in magnitude. In the Agricultural Experiment Stations of the several States investigations are in progress relating to the influence of the breeds of cows on milk and butter production. These studies extend also to the cost and effect of different feeding stuffs in their relations to the yield of milk and the percentage of butter fat therein. The advantages of deep and shallow setting of milk, the influence of temperature on the percentage of cream obtained, the profit of using centrifugal separators, and the use of the by-products of skim milk and milk sugar are all in process of investigation for the benefit and information of dairy farmers. In some States dairy schools have been established where students are taught the science and art of dairy farming. Even if in former times there may have been some apology for the use of nostrum and humbug in milk and butter production, the advancement of knowledge on these subjects will no longer excuse it.

Correction—Read "bottom" instead of "top" on page 9, lines 4 and 13 from bottom of page.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 13.

CRANBERRY CULTURE.

BY

WILLIAM SAUNDERS,
Superintendent of Gardens and Grounds.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE

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1894.

FARMERS' BULLETINS.

The bulletins of this series may be obtained by applying to the Secretary of Agriculture, Washington, D. C. The following have been previously issued:

Farmers' Bulletin No. 1. The What and Why of Agricultural Experiment Stations. (A brief explanation of the object, origin, and development of the stations, their work in Europe and in the United States, and the operations of the Office of Experiment Stations of the Department of Agriculture.) Prepared by the Office of Experiment Stations. Pp. 16. Issued June, 1889.

Farmers' Bulletin No. 2. The Work of the Agricultural Experiment Stations. (Illustrations of station work in the following lines: Better cows for the dairy; fibrin in milk; bacteria in milk, cream, and butter; silos and silage; alfalfa; and field experiments with fertilizers.) Prepared by the Office of Experiment Stations. Pp. 16. Issued June, 1889.

Farmers' Bulletin No. 3. The Culture of the Sugar Beet. (Treats of the climatic conditions, soils, fertilizers, and cultivation required by the sugar beet, cost of growing, time to harvest, and method of siloing; describes briefly the process of beet-sugar manufacture, and gives statistics of sugar production and consumption.) By H. W. Wiley, Chemist of the Department of Agriculture. Pp. 24. Issued March, 1891.

Farmers' Bulletin No. 4. Fungous Diseases of the Grape and their Treatment. (Describes downy mildew, powdery mildew, black rot, and anthracnose of grapes, and gives instructions for their treatment and estimated cost of remedies.) By B. T. Galloway, chief of the Division of Vegetable Pathology. Pp. 12. Issued March, 1891.

Farmers' Bulletin No. 5. Treatment of Smuts of Oats and Wheat. (Describes the smuts of wheat, oats, and barley, the damage they cause, and the various methods of treatment which have been found useful for their prevention.) Prepared by the Division of Vegetable Pathology. Pp. 8. Issued February, 1892.

Farmers' Bulletin No. 6. Tobacco: Instructions for its Cultivation and Curing. Prepared by John M. Estes, special agent. Pp. 8. Issued February, 1892.

Farmers' Bulletin No. 7. Spraying Fruits for Insect Pests and Fungous Diseases, with a Special Consideration of the Subject in its Relation to the Public Health. Prepared by the Divisions of Entomology and Vegetable Pathology. Pp. 20. Issued April, 1892.

Farmers' Bulletin No. 8. Results of experiments with inoculation for the Prevention of Hog Cholera. By D. E. Salmon, chief of the Bureau of Animal Industry. Pp. 40. Issued May, 1892.

Farmers' Bulletin No. 9. Milk Fermentations and their Relations to Dairying. Prepared in the Office of Experiment Stations. Pp. 24. Issued July, 1892.

Farmers' Bulletin No. 10. The Russian Thistle and other Troublesome Weeds in the Wheat Region of Minnesota and North and South Dakota. Pp. 16. Issued April, 1893.

Farmers' Bulletin No. 11. The Rape Plant: Its History, Culture, and Uses. By Thomas Shaw, professor of agriculture in the Ontario Agriculture College. Pp. 20. Issued June, 1893.

Farmers' Bulletin No. 12. Nostrums for Increasing the Yield of Butter. By Harvey W. Wiley, Chemist of the U. S. Department of Agriculture. Pp. 16. Issued June, 1893.

CRANBERRY CULTURE.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Superintendent of Gardens and Grounds,
Washington, D. C., December 9, 1893.

Sir: The manuscript of Farmers' Bulletin No. 13, on the cranberry, is herewith transmitted for publication. The bulletin is mostly compiled from articles published in various annual reports of the Department and from the "Handbook of Experiment Station Work."

Respectfully,

William Saunders,
Superintendent of Gardens and Grounds.

Hon. J. Sterling Morton,
Secretary of Agriculture.

INTRODUCTION.

THE WILD CRANBERRY.

The American cranberry (*Vaccinium macrocarpon*) is found in a wild state in boggy land throughout the northern portions of the United States, in parts of Canada adjacent, as well as in the marshes of the coast and in the glades of the Alleghanies as far south as Virginia and North Carolina. It is also found in South America.

The cranberry is supposed to have been named from the appearance of its bud. Just before expanding into the perfect flower the stem, calyx, and petals resemble the neck, head, and bill of a crane—hence the name "craneberry" or "cranberry."

The plant belongs to the heath family, and is a small hardy shrub with evergreen leaves, and acid edible fruit, varying in color from light dull pink to a dark purple.

WHERE THE CRANBERRY IS GROWN.

The cultivation of the cranberry was commenced in the early part of the present century, but until about forty years ago was conducted on a very limited scale. The first culture was in the vicinity of Cape Cod. The crop of the country is divided into three divisions, namely, the New England, the New Jersey, and the Western. The New England crop includes all raised in the New England States, three-fourths of which is raised in the vicinity of Cape Cod; the Western crop includes that gathered in Michigan, Wisconsin, Minnesota, Iowa, and northern Ohio and Indiana.

Although the plant is indigenous to both continents and grows wild in many parts of the world, yet the American cranberry is the largest, deepest colored, and the richest flavored that appears in the European markets.

CONDITIONS FAVORABLE TO PRODUCTION.

Wherever the cranberry grows naturally it indicates the conditions most favorable to its production. It chooses locations well supplied with moisture, and a peaty, or sometimes silicious, soil, free from any mixture of clay. Peat is most favorable to luxuriance of the vine, but the presence of silex also, in considerable quantity, is necessary to productiveness and the finest fruit, as it hardens the wood, prevents too vigorous growth of vines, and discourages the growth of weeds.

On pure, deep, black peat the cranberry vine will grow more rapidly than in any other soil. A single crop will perhaps be obtained, and then the vines become abortive. The same is true of vines grown on rich intervals, if the wild grasses are kept out. The vines in such situations are very rank, the uprights being of twice the length they attain in productive bogs; and on comparing the two it will be found that the unproductive vines are soft and flimsy, while the productive ones are hard and stiff. A careful chemical analysis of the two would probably disclose the fact that the productive vine contains more silex in its constituent parts than does the unproductive. That this is true is shown by the touch alone. The productive vines are harsh, and when drawn between the fingers the silex with which they are coated grates the skin.

LIMITS OF SUCCESSFUL CULTIVATION.

The limits between which this fruit may be successfully cultivated are stated by an intelligent observer to be the thirty-ninth and forty-second degrees of latitude; but the limit may be greatly extended southward in the Alleghanian ranges, and at least thirteen degrees northward on the western coast of the continent, owing to the ameliorating influence of ocean currents upon the climate of that coast; and we find that cranberries grow in abundance upon the large island of Kodiak, south of and adjacent to Alaska, and of as good quality as those cultivated upon Cape Cod.

REMUNERATIVE NATURE OF THE CROP.

Unlike most other agricultural productions, cranberry vines, growing upon land adapted to them, require no expenditure for manure and no tilling to keep them in good condition. When once established, they will last for years, yielding good returns as regularly as ordinary farm crops. These facts, in connection with the high price of the fruit, render cranberry culture a most remunerative business.

It requires a very considerable expenditure of labor and money to start the business, and after that, much patience to reap the reward; but when once a good meadow comes into bearing, he who owns it may congratulate himself upon possessing something that is pleasant to look after, and that is profitable also.

SOIL.

AUTHORITIES REGARDING THE SORT OF SOIL.

Observation shows that the cranberry usually chooses a peaty, or a silicious, moist soil, and continuous success in its cultivation has been achieved upon such soils only. Prof. Agassiz says:

> Never use the drift formation in preparing cranberry grounds. Use silicious sand that has been entirely separated from loam by the action of water.

An observant cranberry-grower of New Jersey says:

> Experience has proved that for the successful cultivation of this fruit the following are requisites: First, a peat, or muck soil, free from loam or clay; second, clean beach sand for covering the peat; third, a dam and water to overflow the vines when necessary; fourth, thorough drainage.

These conclusions are warranted by the experience of cranberry-growers generally, and while, in very favorable localities as to climate, the winter flooding for the protection of the vines may be omitted, and while it is true that some have succeeded in raising good crops upon pure peat, and also upon sand alone, still these variations from the foregoing rules are at the great risk of the cultivator, and should not be practiced except after careful experiment.

THREE KINDS OF SUITABLE SOIL.

There are three kinds of ground suitable for raising cranberries. The first is what is called "savanna," being low spots of ground with grass or small bushes, and covered with water during the winter and spring, but becoming dry during the summer. These spots have a thin coating of vegetable mold overlying white sand. The second is a mixture of sand and muck to a depth varying from 6 to 10 inches, underlaid with sand and covered with scanty vegetation, the bottom, or subsoil, being hard sand. The third is a deep muck, usually along a stream affording a growth of white cedar, or sometimes maple trees and bushes.

UNSUITABLE SOILS.

It is said that swamps in which the prevailing trees are gum are unsuited to the cranberry. They indicate cold spring water, which is inimical to the growth of this plant; it requires pure water, but not too cold.

The cranberry can not be successfully cultivated on the "drift formation." Hundreds of experiments have been tried, and all have proved to be failures. It is unnecessary to give details; they would fill a volume and be of little practical utility. Prof. Agassiz describes the "drift formation" as being that portion of the earth's surface which was formed by glacial action, and consisting of rocks not in place—that is, loose and not in solid ledges—gravel, clay, and loam. This definition is plain and simple, and any farmer will understand it and be able to distinguish drift as soon as he sees it. In that formation strata of sand are often found, but it usually contains some loam, and it is better to avoid its use. Bogs naturally well adapted to the growth of the cranberry have been ruined by using drift material in preparing them. In some bogs where partly drift and partly alluvium was used, the exact line between the two can be traced by the difference in the growth and appearance of the vine.

THE BEST SORT OF SOIL.

The "alluvial formation" is the only one on which the cranberry can be successfully cultivated. Though this formation includes the most barren and the most fertile soils—the driest and the most damp—yet its character is well marked, and it can be easily distinguished. Sand or quartz-rock pulverized or granulated is alluvium, separated from the drift by the waves and currents of the ocean, and elevated by the action of the winds and waves. The deltas or rich interval lands near the outlets of rivers are alluvium and are formed by the subsoiling of the finer particles brought down by the current of the stream. The mud found in the narrow bogs and creeks near the seashore is of the same character. Salt and fresh meadows, formed partly by such deposits of mud and partly by decayed vegetable and animal matter, belong to the same class. Peat differs from marsh mud only in the fact that one is formed in fresh water and the other in salt water. There are two, if not three, distinct varieties of peat; but all peat and all mud, whether fresh or originally salt, seem to have the same influence on the growth of the cranberry, and may be regarded as practically the same.

PREPARATION OF THE LAND.

The best soil for the cranberry is beach or quartz-sand, overlaid by about a foot of turfy peat. In preparing such bogs, all that is needed is to subsoil the same, bringing about 3 inches of sand to the surface. Underlying the deeper peats, the sand has become indurated, but on exposure to the air crumbles like meal or lime, and may be a useful top dressing. If the peat is deep and covered with rushes, wild grasses, or bushes, the whole must be pared over down to the bottom of the roots and removed, and the bog covered with beach or quartz-sand from 5 to 15 inches in depth.

On rich interval lands the same precautions must be used. If a thick coating of sand is not first spread over, it will be difficult to keep out the wild grasses, and if not kept out, the cranberry vines will, as on the deep peats, make too much wood and be unproductive. Some interval lands are naturally adapted to the growth of the cranberry. Such are usually found near the sources of streams or on the borders of rapid rivers. They contain much sand and fine gravel, and and are easily brought into cultivation.

In preparing the land the object is to afford to the plant the elements needed for its successful growth, to give it entire possession of the ground, and to protect the young plants until they attain full vigor, when they are able to maintain themselves in health without further attention.

DITCHING.

Where savanna lands have been "turfed," the sod or turf is placed in a wall or embankment from 4 to 6 feet wide and of a height equal to the width. The ground is then plowed, the roots and stumps being removed or burned, when the land is ready for planting. Ditches must be made around the lot inside the walls, with cross ditches at distances varying from 100 to 300 feet, and of a depth (6 to 12 inches) depending on the character of the land, so that it may be flooded in winter and in summer and rapidly drained, provided there is not a permanent stream of water, which this kind of land seldom has. The black land is treated in much the same manner, except that it is usually found on the banks of, and contiguous to, a stream of water by which it may be flooded, and in this fact, and probably in the greater quantity of muck over the sand, its superiority over the savanna land mainly consists.

There are many abandoned mill ponds which are readily available for cranberry parks at comparatively small expense, and are much sought, as the dams are already erected and water is abundant.

The kind of land that has the deep muck bottom of cedar or other swamps is by far the most expensive kind of ground to prepare, yet when properly prepared it is the most valuable, because of the larger and more certain product, as well as of its more permanent fertility. In moist seasons the sand or savanna ground yields generous crops, but in very dry seasons the amount of fruit is much reduced.

PREPARING SWAMP LANDS.

The swamps are usually covered with cedars, bushes and stumps, and, as they are wet, require thorough drainage, and, being soft and miry, the labor on them is difficult and tedious. When these incumbrances are removed, the whole surface must be covered with a coating of 4 to 8 inches of sand. The sand is taken from the shores where it usually abounds and scattered over the muck, when, if properly drained and ditched, it is ready for the vines. The sand is essential, for, while the vines will grow luxuriantly on the muck, so will the weeds and grass, and the vines would be smothered and choked. The silex is a necessary ingredient for the health of the plant. Pure white sand is also essential. Clay, or even a loamy sand, is inimical to the cranberry and should be studiously avoided.

A good test for the proper sand or gravel to be used is this: Take a portion of the soil and compress it tightly in the hand; if it is suitable it will fall apart upon being released; but if composed in part of loam, it will adhere together after the pressure is removed, thus indicating its unsuitability.

The cost of preparing and planting varies with the character of the ground. The savanna, which requires simply "turfing," when it is ready for the plow and then for planting, is the least expensive, and, it may also be remarked, the least valuable.

The depth of sand required to be spread on the surface depends upon the depth of the peat. If the latter is only a foot or two in thickness, 5 inches of sand is considered sufficient; if it is several feet thick, at least a foot of sand is required to make a good bog. The more sand there is used, the longer it requires to bring the vine into a bearing state.

Much stress is placed on the quality of sand by all cranberry growers. It is claimed that coarse, clean, sharp sand is best adapted to the growth of the vines. In some cases only an inch of sand is placed over the peat bottom, and then it is planted with vines, the roots growing directly in the muck. In other cases as much as 10 inches of sand has been placed over the muck sand, which, however, conveys the soluble humus of the peat to the roots of the plants. There is always a rankness of root and vine growth when the vines are planted directly in peat, and, as the growth of plants is continued longer under such conditions, they are longer in bearing their fruit. The same remarks apply to plants which are heavily manured and constantly supplied with abundance of water.

It has been found in every case where the runners have been sanded to the depth of about an inch and properly watered they readily take root in the fresh sand and produce a fine growth of lateral branches. In some cases sanding the vines in this way has as good an effect on their growth as an application of guano. It is believed by many successful cranberry growers that the runners of the vines should be sanded at least once in four years when practicable, and some growers sand them as often as once in three years. The great advantage derived from the sanding process consists in the stimulating of new roots along all the runners embedded in the sand. The original roots decay as the vigor of the new ones increases, but the sand also protects the runners from extreme heat and premature frost.

The true character of peat in relation to cranberry growth is still a matter of doubt; but one thing is evident, namely, that masses of peat will always absorb and retain a large amount of water, and will thus tend to keep moist the sand on the top. Certainly the humus of the peat is not itself absorbed by the roots of plants, but humic acid seldom is free from ammonia, and the oxidation of peaty matter may also contribute to root and plant growth by supplying carbonic acid, which is one of the essentials of plant food.

CULTURE.

VARIOUS METHODS OF PLANTING.

In planting cranberry vines several modes have been followed.

Sod-planting, by taking from their native marshes sods containing cranberry vines, moss, turf, etc., and placing them on prepared or unprepared meadows, was formerly practiced, but is now discarded.

Hill-planting, with bunches of clean vines, in drills 2 feet apart each way, and a handful of vines planted at each intersection, is practiced; but large bunches have a tendency to dry up and become woody, thus injuring the plantation.

In drills requiring no sanding, but susceptible of being prepared with a plow, the best methods is to "strike out" the ground with a plow, in rows 3 feet apart, and scatter the vines thinly and evenly along the furrows, putting only 1 or 2 in a place. They should be inclined against the "land side," projecting 4 or 5 inches above the surface, after which the hoe is required to fill up the furrows and thoroughly cover the roots. This causes them to sucker and grow more luxuriantly than when left standing upright, to be swayed by the winds.

On soils properly prepared by spreading sand over muck or peat, the best mode is to mark out the ground 14 inches apart with a small sled having three runners; the vines are then dropped in these marks, say 2 in a place, 14 inches apart in the rows, and pressed into the ground with a spade-like tool placed on the vine, about one-quarter the distance from the root to the top. The roots of the vine should be pressed into close proximity to the muck below, that they may be stimulated to grow more rapidly.

Spreading the vines evenly over the surface of the meadow, and then covering them about an inch deep with sand, has succeeded well in New Jersey. The young shoots come up through the sand as thick as wheat, making an excellent growth, and the whole surface is soon matted with them. This mode requires more vines than the others, but yields a crop sooner than by planting in any other way.

Sowing by cuttings can be successfully done, the vines being passed through a straw-cutter, and chopped into pieces about an inch long; they are then sown like oats upon evenly prepared surfaces and harrowed in. This must be done early in the spring and upon moist ground, so that the cuttings will become well rooted before the heat of summer.

Attempts have been made to grow them from seeds, but owing to the longer time required for the vines to become productive and the increased expense of keeping them clean this system has been abandoned for general culture.

DRAINAGE.

Great care should be taken in selecting the vines to procure those which yield large berries. The shape of the fruit is of little consequence, the great desideratum being to obtain berries of good size and color. Until the vines are well matted it is important to keep the meadow thoroughly drained at least one foot below the surface. It will generally be found necessary to go deeper than that to effect a thorough drainage, without which the vines will not thrive. Even if planted on ground well adapted to their growth, if the meadow is allowed to remain very wet the vines will make little or no growth. When properly drained a good meadow will become matted in three years, although some of the most permanent plantations have required a longer time to come into full bearing, owing to the dampness of the soil.

TIME OF SETTING AND SUBSEQUENT TREATMENT.

The cranberry vine is very tenacious of life, and will grow if set at almost any season, but the spring of the year is usually considered the best time, and as early in spring as possible, to secure a good growth.

Though various methods of treatment for the second and third years have been pursued, experience has demonstrated that the simplest mode is the best. The hoe is rarely needed to eradicate weeds and grass, and its use, or that of the plow and cultivator used by some, is injurious. The weeds and grass are best eradicated by hand-pulling, which prevents injury to the roots and tender running vines. The hoe may be used to level the surface and make drains from low spots so that there shall be no stagnant water. Sluices should be made to carry the water off rapidly after the flooding or after heavy rains.

FLOODING THE VINES.

The usual time for flooding is from the last of October to the first of May, and 18 to 24 inches of water are sufficient.

Some cultivators advise a flow of water for twenty-four hours in the first week in June, when it can be done rapidly and safely. The water is then drained off and the plants, under the genial influences of the sun and moisture, are soon covered with tiny pink-white blossoms and the fruit quickly appears. All that is now needed is to keep a supply of moisture during the drought of summer, till the harvest calls for more active operations.

A flood gate is a very important item in cranberry culture. In many places, such as on level and high lands, a cheap mode of ditching and a very inexpensive gate formed of a few slabs are all that is necessary. In some cases nature provides all the requisites. Flooding protects the vines from winter frosts, and is one of the means employed to destroy mice, roaches, grasshoppers, and a variety of insects which consume or destroy many thousand bushels of berries annually. Ice is sometimes very destructive to vines when proper attention is not paid to winter flooding. Should a severe frost set in before the vines are wholly covered with water ice will form on the surface, thus securing the tops in ice; a further supply of water flowing under the ice may float it upward and drag the vines from their roots.

It should be remarked that the continued success of a cranberry field depends very greatly on the readiness with which water can be admitted upon the surface or withdrawn from it.

At Cape Cod, Mass., the cranberry cultivators take advantage of the winter and sand their vines while covered with ice. They cart the sand over the ice and spread it evenly over the surface. When it melts the sand is deposited over the vines. This practice is not only economical, but it also saves the vines from being trampled upon.

CRANBERRY FERTILIZERS.

Cultivators of the cranberry are divided in opinion on the subject of fertilizers, as to their use in any case, as well as to the kind, quality, and quantity to be used, and whether in the spring or in the fall. Some have used guano to great advantage. One application on heavy soil showed evidence of its value for several years afterwards. It is used as follows: Two quarts of guano, combined with one pail of moist sand, is spread on the soil at such a rate that from 50 to 250 pounds of guano will be required on each acre. Guano and bone dust have been used to the advantage of growth of vines and size of berries, but it has no visible influence in preventing rot or scald. On high land savannas, in dry seasons, guano may prove injurious, in consequence of its free ammonia, which acts as a caustic on the roots, while in seasons of light rains it will prove of great advantage.

Excessive fertilization produces a rank crop of vines and frequently of the fruit. The perfect growth of berries can be attained only by the production of light wood on vines. The continued growth of succulent vines, caused by overfertilization, deprives the berries of material which should be used for their growth and perfection toward the ripening season.

GATHERING THE CROP.

The month of October is the proper season for gathering the crop. The berries are sometimes gathered by means of a rake, called the cranberry rake, but the finest and most valuable berries are those gathered by hand, as are strawberries.

Cranberries free from spots and carefully handled to prevent bruising will keep well in places suitable for storing apples or other fruit, with as low a temperature as possible to avoid freezing. Thorough ventilation is also very essential.

When gathered under a high temperature they should be placed under shade in open trays to cool.

Previous to shipping cranberries they should be run over a platform slightly inclined. The rotten and bruised fruit will not run off, but will stick on the platform, and may be scraped off and thrown away.

SOLAR HEAT.

Dr. Taylor says:

> It is generally supposed that the cranberry plant will not grow successfully farther south than southern New Jersey. This belief is based upon the fact that a large portion of the crop is destroyed by excessive high temperatures, but when we find in those favored cranberry lands 10 acres of successful vines and berries side by side with as many acres rotting and scalding, under the same climatic conditions, we come to the conclusion that if the solar rays were directly the cause of rot all would suffer alike, as it is well known that many bogs for a period of from ten to twenty years have successfully grown fruit free from rot. High temperatures, therefore, can not be the general cause of rot. Indeed, it seems to perfect the fruit when the soil and rains are highly favorable. What is wanted is a rich soil, a constantly moving moisture or water at the roots, and a sufficiently high temperature. Springy land has been found to be very favorable to the growth of sound vines and berries. I am convinced that in the District of Columbia and in the States of Maryland and Virginia there are many patches of bog lands suitable for cranberry culture, which are of little or no value at present.
>
> We have sometimes been called upon to explain why it is that on the same branch or vine sound and rotten berries will frequently grow side by side. It is a well-known fact that the whole vine does not blossom at the same time. There is a first and second bloom on the same pedicel. Berries form on the same stalk which bears the blossom for a second and third berry. The first bloom and berry may get its first start with rain and sunshine sufficient to bring it to perfection, while the second bloom and fruit may be deprived of this favorable start.

COLORING WILD BERRIES.

> It is the custom of the West Jersey Land Company to gather the wild berries while green. An open shed is prepared, under which the berries are placed on the bare ground, spread evenly, and exposed day and night from six to eight weeks to color. Berries have been colored to a high red by this process and perfectly free from rot. The cultivated berries are not exposed in this way, but are first cooled, cleaned, and freed from all unhealthy berries by hand picking or machinery.

INJURIOUS INSECTS.

There are drawbacks to the results and enemies to the vine and fruit to be resisted, as with almost all other fruits. The cranberry has suffered both in fruit and vine from the ravages of insects, sometimes to the extent of a total denuding of the vines of their leaves and the loss of entire crops. It is to protect the vines and fruit against these, as well as against the effect of frost upon the unripe berries, that flooding is regarded as necessary by experienced growers.

There are a number of insects preying on the cranberry, the more important of which are the black-headed worm, the yellow-headed worm, the fruit worm, and the tip-worm.

THE BLACK-HEADED WORM.

The black-headed worm (*Rhopobota vacciniana*), also called vine worm or fire worm, is the larva of a moth. It does not fly very readily in the daytime, but may be found starting up occasionally. There are two broods each year. The eggs retain their vitality during the winter and hatch early in May. The larvæ eat the leaves, spinning them into a web at the same time. The larva is a small, slender, velvety-green caterpillar, with a black head. The second brood appear about the time of blooming and are more destructive than the first. They web more leaves together and bite the leaves just enough to kill them and destroy all the flowers. In two or three days they can change a bog from green to brown.

THE YELLOW-HEADED WORM.

The yellow-headed worm (*Teras vacciniivorana*) is somewhat like the above in that the larvæ spin webs and are green in color, but they have yellow heads. The moths are orange in summer and slate gray in autumn. The gray ones spend the winter on vines and under rubbish. The eggs are laid early in spring and hatch in May. The caterpillar changes into an orange-colored moth in about a month. There are usually three broods each season, the last being the gray moth, the larvæ of which are reddish in color.

If the water supply can be controlled, drawing off the water early and flooding for two days just after eggs of the first brood begin tc hatch will kill most of them. Flooding until late in the spring is also beneficial. Pyrethrum, dry and in infusion, has been tried with favorable results. White hellebore is good. Tobacco decoction, 1½ pounds to a gallon of water, gives sufficient return to more than pay for itself. Kerosene emulsion as a spray applied to the vines was tried quite effectively, as were also Paris green and London purple (1 pound to 150 gallons of water) sprayed over the plants just after the larvæ were hatched. If they begin webbing, use kerosene emulsion.

THE FRUIT WORM.

The fruit worm (*Acrobasis vaccinii*) is the larva of a gray moth. It shades to nearly black and is splotched with white. The eggs are laid on the berry when just forming. They hatch in five or six days and soon eat their way into the fruit, closing the opening with a web of fine silk. After attaining about half their growth they seek another berry and so on until they mature. The larva is about half an inch long, green tinged with red, and reaches maturity in September. Spraying the vines with Paris green or London purple just after the fall of the flowers is an effective remedy.

THE TIP-WORM.

The tip-worm (*Cecidomyia vaccinii*) eats out the terminal bud, causing laterals to come out. It stunts the plant for a short time, but is not generally considered troublesome.

A minute scale insect has been found abundant in some bogs.

FUNGOUS DISEASES.

CRANBERRY SCALD.

Cranberry scald is a fungous disease well known to cranberry-growers, often causing a loss of half the crop. It receives its name from the scalded appearance of the affected berry.

At first a portion of the berry becomes soft and the skin tense and of a reddish brown color. Sometimes only a portion of the berry decays and the spores of the fungus may be seen in the minute dark specks. A rank growth of fungus filaments is always associated with the scald. The same filaments are to be found in the roots, stems, and leaves of the affected plants, and similar pustules develop on the leaves and fruit. Various fungicides have been tried without obtaining any very satisfactory results. However, it has been learned that covering the bog with a layer an inch deep of fresh earth, clay, or sand will nearly always give relief from the scald. This can best be done when the bog is flooded. This treatment may be too expensive to pay. This disease seems to be due to conditions of the soil and water, and these must be looked after if anything is to be done with the scald.

Investigations made in 1874, by Dr. Thomas Taylor, Microscopist of the Department, proved that the rot of the cranberry is caused by the fermenting of the muck and the stagnating water in which they are grown, and sometimes by the scorching sun. Previous to this growers had given no attention to the condition of the roots of the vines or to the soil in which they grew. His observations proved that the rot was confined to the parts indicating fermenting soil, while the sound berries grew on the well-decomposed soil.

He visited many places in New Jersey and Massachusetts in company with several practical cranberry growers. Of one plantation visited he says:

> The vines on this plantation rotted in spots last season. An examination of these spots showed undecomposed peat and unhealthy roots, the latter being very large and closely matted. Having stated to the cranberry growers accompanying me that fermenting soil and stagnating water were probably the principal causes of the

rot, I was informed that, although my theory held good thus far, there was a neglected cranberry plantation near Bricksburg, the water of which they believed to be stagnant, as it had no visible outlet; but notwithstanding, the fruit of the bog had not been affected by the disease. An examination showed that the water which flooded it was perfectly fresh, being supplied probably by means of springs, and passed off through the sand. The whole surface was covered with a dense growth of moss and weeds interspersed with cranberry plants. The cranberry roots were growing in the moss and confined to it. They were short, of a whitish color, and very healthy. Sand to the depth of 8 inches had at one time been spread over the peat muck. I cut through it and found it to be very pure and free from any odor. I have also examined the roots of the cranberry plants as found growing in the wild state, and in all cases have found them to be healthy and similar to these. I have thus far failed to discover any healthy cranberry vines growing in stagnant water.

He further says:

Two specimens of vines, one healthy and the other unhealthy, were received by the Department, and a specimen of the soil in which each plant grew. An examination of the roots of each vine showed that the one which bore rotting fruit had much larger and darker roots than the other. The peaty muck in which the healthy plants grew has a pleasant odor, and was not in a fermenting condition, while that of the unhealthy plant was in a condition of fermentation and had the odor of sulphureted hydrogen. These facts led me to believe that the sour condition of the soil was the primary cause of the rotting of the berries.

Before investing in cranberry culture—

he continues—

attention should be paid to the condition of the soil; for on that depends the quantity of water necessarily required for the purposes of irrigation. When water is very limited in supply it should be protected from the sun's rays in some practical way. Small dams or ponds, used as reservoirs, might be protected by shade trees, and in many cases streams might be easily protected in this way. A limited supply of water during high temperatures, when the water becomes quickly heated, is hurtful to the vines, especially when the subsoil has not been well decomposed. Under such conditions fermentation will be promoted, producing organic acids and sulphureted hydrogen in the vicinity of the roots; while a much larger flow of water in the ditches would cool the substratum of the bogs and remove at the same time all soluble noxious substances.

Recent observations demonstrate that dense fermenting muck may be greatly improved by the use of caustic lime and a bountiful supply of water. The lime reduces the consistency of solid peat and the running water removes the useless salts of lime which form during the fermentation and oxidation of the mass. The peaty matter, in the course of two or three years, is rendered very porous and free from all bad odors. As much as 100 bushels of lime to the acre have been used to advantage on heavy muck lands.

CRANBERRY GALL FUNGUS (SYNCHYTRIUM VACCINII).

This disease, although very local in New Jersey, threatens the extinction of the plant in some places. It produces minute cup-shaped, bright red outgrowths upon the leaves, stems, flowers, and fruit, and so robs the plant of vitality as to render it worthless. It also attacks the azaleas, huckleberry, wintergreen, and similar plants on the edge of the bog, which are reached by the water at high flood. It is thought that the disease spreads by the water carrying the infection. If the water supply can be controlled, the withholding of water during the winter and spring has been attended with good results. Where such conditions are wanting, burning the bog is the only means of relief known.

OTHER PESTS.

GRASSHOPPERS.

At the second annual convention of the New Jersey Cranberry Association Dr. Taylor speaks of drawings, exhibited by Mr. E. Z. Collins, of Waterford, Camden County, of—

> a very simple combination of spars, canvas, and sheet-tin trays, for the destruction of grasshoppers. The spars combined represent the Roman letter A, along the sides of which the trays and canvas are secured. The canvas is stretched perpendicularly, extending upward about 2 feet and downward about one foot, touching the top of the vines when in use. The operator walks with the frame, which is strapped over his shoulder. The trays are filled with tar and the canvas is smeared with it. When the person moves along with the framework the grasshoppers are thrown on the tar and secured. From one peck to a half bushel may be destroyed in this way each day. Crickets are not caught by this device. I am informed that mice and crickets eat the berries, while grasshoppers eat the seeds. Many thousands of bushels of fruit are destroyed annually by these pests.

MOSS.

Moss, *polytrichum commune*, which sometimes infests bogs, is objectionable in that it lifts the runners, and prevents them from rooting in the soil. The best way of disposing of moss is to cover it with an inch or two of sand. This remedy may be applied even after the vines are over two years old; the runners should be covered, and the upright branches, if possible, left out. The vines, thus established, will put forth runners and take possession of the clean surface.

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April 26, 18

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FERTILIZERS FOR COTTON.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., March 6, 1891.

Sir: I have the honor to transmit herewith for publication as a Farmers' Bulletin an article on fertilizers for cotton, compiled by J. M. McBryde, ph. d., from accounts of experiments carried on under his direction for several years on the farms of the South Carolina Experiment Station. It is believed that the wide circulation of this information in the Southern States will do much to prevent unnecessary expenditures for commercial fertilizers, which now constitute a great burden on the cotton planters.

Respectfully,

A. C. True,
Director.

Hon. J. Sterling Morton,
Secretary of Agriculture.

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FERTILIZERS FOR COTTON.

INTRODUCTORY.

We have reason to believe from extended observation and experience in the field that hundreds of thousands of dollars are annually wasted by farmers in the lavish and injudicious application of fertilizers on cotton. In soils abounding in potash, potassic fertilizers, such as kainit, muriate of potash, etc., are often unnecessarily applied at a cost amounting to $4 or $5 per acre. It is especially timely at this season, when the farmers are about to plant their crops for the year, to discuss the manurial requirements of cotton, and to give in condensed form the results of careful and long-continued experiments bearing directly upon this question. The subject is so broad as to require subdivision. It will, therefore, be discussed under the following heads: Does cotton require potash, phosphoric acid, and nitrogen? If so, in what amounts and in what forms? Does it need lime? Will copperas prevent its rusting? At what time or times should nitrate of soda be applied? How should the fertilizers be applied?

DOES COTTON REQUIRE POTASH, PHOSPHORIC ACID, AND NITROGEN?

It is now held that potash, phosphoric acid, and nitrogen are the three most important constituents of manures, and the only ones generally called for by soils. In most soils there is a sufficiency of the other elements of plant food—such as lime, magnesia, soda, sulphur, iron, etc. In a limited number, lime is sometimes deficient. It can, however, be easily supplied by cheap forms of calcareous manures.

In beginning experimental work bearing upon these questions a few years ago, when director at the South Carolina Experiment Station, we had little in the way of published information to guide us. It was generally believed that cotton required phosphoric acid, but opinion was divided as to the importance of potash and nitrogen. In deciding upon the amount of each constituent to be used in our tests several courses were open to us: To take arbitrary amounts of each; to accept the percentages of the ammoniated acid phosphates offered for sale in our markets; or to employ the amounts contained, according to analysis, in a crop yielding a given weight of lint per acre. The last was preferred as offering a convenient working hypothesis, with the full knowledge of the fact that in determining the manurial requirements of any crop analysis is not an infallible guide. It was considered better, however, than a mere rule of thumb.

We found, to our disappointment, that the published analyses of the parts of the cotton plant were, with the exception of those of the seed, all old and probably unreliable. We were obliged to use them in lieu of anything better, but began at once an elaborate series of analyses and determinations of our own.

According to the old analyses, the plants of a crop of cotton yielding 300 pounds of lint per acre contain 52 pounds of nitrogen, 26 pounds of phosphoric acid, and 48 pounds of potash. These amounts we assumed to be the full applications or doses required to produce a crop giving 300 pounds of lint per acre. Where not otherwise stated, these amounts were supplied as follows: The nitrogen by 330 pounds of nitrate of soda (containing 16 per cent of nitrogen); the phosphoric acid by acid phosphate (containing 16 per cent of phosphoric acid—about 15 per cent available and 1 per cent insoluble); the potash by muriate of potash (containing 50 per cent of potash).

In the following pages the full dose of any constituent is conveniently represented by the numeral 1 placed before its name; 1 nitrogen, for example, means 52 pounds nitrogen (furnished by 330 pounds of nitrate of soda, etc.), 1 potash means 48 pounds of potash, etc. Smaller or larger amounts are expressed in the same way: 2 phosphoric acid means a double dose or 52 pounds of phosphoric acid, ½ potash means the half dose or 24 pounds of potash, etc.

Several plats were left unfertilized, some received only one constituent, others received two constituents, and others, again, all three constituents. The full dose of a constituent was used in every case. Each test was continued on the same plats from year to year. Every test was carefully duplicated, the two plats being separated from each other in the experimental field by considerable intervals.

The station had two farms, situated in different sections of the State. Every test was separately made at each farm and carefully repeated for three years. This duplication and repetition gave us valuable data for verifying and correcting results. The missing plants in every plat were carefully determined and allowed for in order to reduce the plats to a uniform stand. By close observation the amount of error incident to the work—errors due to differences in the mechanical and chemical condition of the soils in the plats employed and numerous accidental causes—was accurately determined. This error averaged ±30 pounds of lint cotton per acre for the three farms in 1888, ±32 pounds in 1889, and ±32 pounds in 1890, making an average of ±31 pounds for the three years.

From an examination of the soils of the two farms and inquiry as to their history it was assumed, at the beginning of our tests, that the particular soils to be experimented on would give, without manures of any kind, about 50 pounds of lint per acre. The results showed that the unfertilized plats, thoroughly prepared and cultivated, gave somewhat better returns than this. The soils selected were very thin, being greatly exhausted by years of improvident tillage.

The agreement in the results of the tests on the two farms is so remarkably close as to show the controlling influence of the plant, and therefore to justify us in using the combined averages of the two farms:

Combined annual average yields of lint per acre on two farms for three years.

Fertilizer.	1888.	1889.	1890.	Average of three years.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Unfertilized	98	83	73	85
Fertilized with—				
Potash	120	83	91	98
Phosphoric acid	168	156	154	159
Nitrogen	109	73	114	99
Potash and phosphoric acid	191	192	171	185
Potash and nitrogen	180	161	168	170
Phosphoric acid and nitrogen	203	206	240	216
Potash, phosphoric acid, and nitrogen	298	316	339	318

Taking the averages of the unfertilized plats as unity, the comparative average results of the several applications for the three years can be conveniently shown as follows:

Comparative average yields of lint for three years.

Fertilizer.	Upper farm.	Lower farm.	Two farms.
Unfertilized	1.00	1.00	1.00
Fertilized with—			
Potash	0.96	1.31	1.14
Phosphoric acid	2.00	1.78	1.89
Nitrogen	1.58	0.83	1.20
Potash and phosphoric acid	2.19	2.16	2.17
Potash and nitrogen	1.93	2.05	1.99
Phosphoric acid and nitrogen	2.74	2.40	2.54
Potash, phosphoric acid, and nitrogen	4.02	3.52	3.77

The combination of potash, phosphoric acid, and nitrogen gave an average increase, as compared with the averages of unfertilized plats, of 300 per cent at the upper farm and 250 per cent at the lower, and an average yield of about 100 pounds more lint per acre than any combination of two of these materials. The figures leave no doubt as to the importance of potash, phosphoric acid, and nitrogen to cotton.

A careful study of the detailed results of the tests may be condensed into the following table, which shows the gain in pounds of lint per acre afforded by adding any one constituent to the unfertilized plats, or to either of the other constituents, or to both:

Increase in yield of lint per acre from applying each of the fertilizing constituents alone or combined with the other two.

Fertilizing constituent added.	Unfertilized.	Potash.	Phosphoric acid.	Nitrogen.	Potash and phosphoric acid.	Potash and nitrogen.	Phosphoric acid and nitrogen.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Potash	13	....	26	71	....	....	102
Nitrogen	14	72	57	....	133	....	....
Phosphoric acid	74	87	....	117	....	158	....

It will be seen that the nitrogen gave better results than the potash, and the phosphoric acid better results than the nitrogen. Taking the combined average of the combination of any two of the constituents as one, the effect of adding the third may be expressed as follows: Potash 1.47, nitrogen 1.72, phosphoric acid 1.87. It is clear from these figures that phosphoric acid was of greater relative importance to the cotton crop than nitrogen, and nitrogen of more importance than potash.

PROPORTIONS AND AMOUNTS OF POTASH, PHOSPHORIC ACID, AND NITROGEN REQUIRED.

Our applications, it will be remembered, were intended for a crop yielding 300 pounds of lint per acre. While the results of the foregoing tests leave no doubt as to the importance of potash, phosphoric acid, and nitrogen, it does not necessarily follow that the amounts supplied were the right ones. The full or theoretical dose may well have been too small on the one hand or too large on the other. In order to determine this point other series of experiments were carried on in which different amounts of each constituent were employed. In one series different amounts of potash were used with full doses of the other constituents; in another series the phosphoric acid, and in a third the nitrogen varied, the other two remaining the same. For convenience the two constituents remaining fixed (as to amounts used) in a series may be called the constants, and the one changing the variant. In stating the results the average yield of lint per acre for the two farms for the three years is given.

POTASH.

In this series phosphoric acid and nitrogen were the constants and potash the variant. Full, double, and half doses (48 pounds, 96 pounds, and 24 pounds) of potash were tested, with full doses of phosphoric acid and nitrogen, with the following results:

	Pounds.
2 potash	329
1 potash	318
½ potash	294

It will be seen that the double dose gave only 9 pounds more than the full dose, and the latter only 24 pounds more than the half dose. The average probable error for the two farms amounted to ±31 pounds of lint per acre. It appears, therefore, that the several amounts gave about the same average results. It has already been mentioned that the potash in this series of tests was supplied by muriate of potash. In another series—which will be discussed later on—undertaken for the purpose of determining the relative values of the several kinds of potassic manures, different amounts of potash were also tested in the form of kainit and sulphate of potash. The full dose of potash in the kainit gave 331 pounds and the half dose 332 pounds; the full dose in sulphate of potash gave 322 pounds and the half dose 295 pounds. With kainit there was a difference of 1 pound in favor of the half dose; with the sulphate of potash, a difference of 27 pounds in favor of the full dose.

The results of the one series strongly support those of the other, and we must, therefore, conclude that the full and double doses of potash were excessive.

PHOSPHORIC ACID.

In this series potash and nitrogen were the constants and phosphoric acid the variant. Full, double, and half doses (26 pounds, 52 pounds, and 13 pounds) were tested together with full doses of potash and nitrogen. The phosphoric acid was supplied by acid phosphate.

	Pounds.
2 phosphoric acid	386
1 phosphoric acid	398
½ phosphoric acid	277

The mean difference between the averages of the double and full doses was 68 pounds for the two farms. The difference between the full and half doses averaged 41 pounds for the two farms. Increasing the dose by 100 per cent seems to have been attended with a corresponding increase of from 65 to 75 pounds of lint. Indeed, increasing the amount of phosphoric acid produced marked effects at the two farms both in this series and in another series of experiments with different phosphatic fertilizers. In the latter series the full dose of phosphoric acid in reduced phosphate (see p. 16) averaged 44 pounds more lint than the half dose for the two farms. It follows, therefore, that double doses of phosphoric acid can be advantageously employed.

NITROGEN.

In this series nitrogen was the variant and phosphoric acid and potash the constants. As nitrogen is the most expensive constituent of fertilizers, it was thought advisable to test it in several different proportions, with full doses of the others. The nitrogen was supplied by nitrate of soda. The full dose amounted to 52 pounds.

	Pounds.
2 nitrogen	269
1½ nitrogen	257
1 nitrogen	318
¾ nitrogen	316
½ nitrogen	269
¼ nitrogen	232

The close parallelism between the results of the tests at the two farms was remarkable. It will be seen that the full and three-quarter doses gave almost exactly the same combined averages—318 pounds and 316 pounds, respectively—and better results than the heavier doses, which probably lowered the yield, as compared with the full dose, by inducing too luxuriant a growth of stem and foliage, or what is commonly known as *weed*. The half dose gave exactly the same yield as the double dose. Reducing the dose by more than 50 per cent unmistakably diminished the yield, as will appear from a comparison of the average of the full and quarter doses. As compared with the quarter dose, the half dose does not show an increase sufficient to make up for its additional cost. That the full dose of nitrogen was excessive, as compared with the half dose, also appears from the results of another series of experiments with different nitrogenous manures in which full and half doses of nitrogen were employed. In that series the half dose of nitrogen in dried blood gave 6 pounds more lint than the full dose, in the cotton-seed meal 33 pounds more, and in the ground cotton seed 7 pounds more.

It follows, therefore, that the three-quarter, full, one and one half, and double doses were excessive, and that the difference in favor of the half dose as compared with the quarter dose was not sufficiently large to meet its additional cost.

The results of the preceding tests taken together show that a crop of cotton yielding 300 pounds of lint per acre requires double the full or theoretical amount of phosphoric acid, but only about one fourth to one half the full amounts of potash and nitrogen.

DOUBLE DOSES OF TWO CONSTITUENTS.

In all the foregoing series of tests except one, two of the constituents were constants, while the third was increased or diminished. It was deemed advisable, in order to test the effect of increasing the amounts of the two minerals (potash and phosphoric acid), or nitrogen and one mineral, to carry on another series in which one constituent should be taken as the constant and the other two as the variants. This series was also intended to be a check upon those discussed above. To present the results more clearly, the double doses of the two constituents will be compared with the double and also with the single doses of each.

	Pounds.
1 potash and 1 phosphoric acid	318
2 potash and 1 phosphoric acid	329
1 potash and 2 phosphoric acid	386
2 potash and 2 phosphoric acid	358

(1) *Double doses of the minerals.*—In the tests under this head the full dose of nitrogen was used in each case and is, therefore, not mentioned in the comparison. In this and the two following statements of results of yield of lint per acre the first three tests are taken from the preceding series.

It is evident that doubling both minerals gave no better returns than doubling only the phosphoric acid, for the difference between the averages of the two applications did not exceed the probable error at either farm. Their beneficial effects as compared with those of the other two were doubtless due in both cases to the increased dose of phosphoric acid.

(2) *Double doses of nitrogen and potash.*—In these tests phosphoric acid (full dose) was the constant.

	Pounds.
1 nitrogen and 1 potash	318
1 nitrogen and 2 potash	329
2 nitrogen and 1 potash	269
2 nitrogen and 2 potash	268

Double doses of nitrogen and potash gave almost exactly the same results at each farm as the full or single dose of nitrogen, and both applications were inferior to the first two, in which single doses of nitrogen were used. Here, again, there is evidence of the injurious effects of excessive doses of nitrogen. The fruit requires phosphoric acid. The heavy growth of weed induced by the excess of nitrogen consumes a large part of the phosphoric acid, when it is present in limited amounts, and the supply fails before the plant has perfected all its fruit. The unseasonable growth is also generally checked or destroyed by cold weather. It follows from this that whenever heavy amounts of nitrogen are employed the phosphoric acid should be correspondingly increased. This statement is borne out by the results of the next tests.

(3) *Double doses of nitrogen and phosphoric acid.*—Potash (full dose) was the constant. The yield of lint per acre was as follows:

	Pounds.
1 nitrogen, 1 phosphoric acid	318
2 nitrogen, 1 phosphoric acid	269
1 nitrogen, 2 phosphoric acid	386
2 nitrogen, 2 phosphoric acid	405

The difference in the effects of the double dose of nitrogen when combined with the double dose and the single dose of phosphoric acid is very striking and abundantly confirms the point made above. The double dose of phosphoric acid gave about the same combined average as the double dose of nitrogen and phosphoric acid. Both show decided gains as compared with the applications containing single doses of nitrogen and phosphoric acid.

The conclusions drawn from the results of the experiments discussed under the preceding heads are still further strengthened by the results of this series of tests.

DOUBLE DOSES OF THREE CONSTITUENTS.

The point may be made, Would not doubling all three constituents give better results than doubling any two of them? Our tests answer it as follows:

	Pounds.
1 potash, 1 phosphoric acid, 1 nitrogen	318
2 potash, 2 phosphoric acid, 2 nitrogen	320

On comparing their combined averages it is apparent that the two applications gave about the same results. It will be asked, Why did doubling all three constituents fail to show any increase, when doubling the phosphoric acid, or even the phosphoric acid and nitrogen, was of such decided benefit to the crop? It can be replied that the excessive applications of potassic and nitrogenous salts (muriate of potash and nitrate of soda) probably acted injuriously upon the crop, especially in the early stages of its growth, and thereby neutralized the beneficial effects of the phosphoric acid. The deficiency of the soils in vegetable matter seriously affected their relations to heat and moisture and unfitted them to respond to heavy applications of commercial fertilizers or chemicals.

In their advocacy of the intensive system of farming some go so far as to claim that "doubling the manure will double the crop." No amount of food will fatten a very lean animal in a few weeks' time. And so with an impoverished soil. It can not be forced into immediate fertility by lavish applications of commercial fertilizers. Its mechanical condition—its physical properties—must be improved by thorough tillage and the addition of vegetable matter. The results of the foregoing experiments show the necessity of caution in the use and application of manures, for they make it clear that with a given amount of phosphoric acid only comparatively small doses of potash and nitrogen were needed and that all amounts of potash and nitrogen in excess of these doses were simply thrown away.

It will be of interest to compare with the above test another in which double doses of the three constituents were employed in connection with vegetable matter. Six tons of good stable manure supply the full or theoretical doses of the three constituents, together with a large amount of humus. Twelve tons will furnish double doses of the three. These two amounts were tested in the series of experiments with nitrogenous manures to be discussed later on. Their average results of yield of lint per acre may be given here as follows:

	Pounds.
1 potash, 1 phosphoric acid, 1 nitrogen (stable manure)	392
2 potash, 2 phosphoric acid, 2 nitrogen (stable manure)	462

Comparing the combined averages of stable manure and the commercial fertilizers it will be seen that in the former the single doses of the three constituents gave 74 pounds more lint and the double doses 142 pounds more than the corresponding doses in the latter. The difference in favor of the stable manure is, in large part, attributable to the beneficial effects of its humus. Comparing, next, the combined averages of the two applications of stable manure we find that doubling the dose, so far from doubling the crop, only gave an increase of 70 pounds of lint. The increase was by no means commensurate with the increased cost of the application. The results of our tests are not opposed to the judicious use of liberal amounts of manures, but only to their lavish and unintelligent employment. The enrichment of an impoverished soil is the work not of months but of years, and it can only be economically accomplished in our climate by turning under green crops and other forms of vegetable matter in connection with applications of fertilizers.

But it may be claimed that heavy applications of fertilizers are cumulative in their effects and will, therefore, pay in the long run. Our observations, covering a period of three years, showed that this was not the case at our farms.

IN WHAT FORMS CAN POTASH, PHOSPHORIC ACID, AND NITROGEN BE MOST EFFECTIVELY SUPPLIED?

Numerous kinds of potassic, phosphatic, and nitrogenous manures are now offered for sale in our markets. Under the first head are generally classed wood ashes, cotton-seed hull ashes, kainit, sylvinit, muriate of potash, and sulphate of potash; under the second, floats, basic slag, bone meal, boneblack, dissolved boneblack, acid phosphate or superphosphate of lime, and phosphatic guanos; under the third, sulphate of ammonia, nitrate of soda, dried blood, fish scrap, tankage, cotton-seed meal, and guanos. When the variety offered is so great the determination of the relative values of the several kinds in each class becomes a matter of importance.

Our tests were confined to the kinds commonly used in the South. The experiments included tests of potassic manures, tests of phosphatic manures, and tests of nitrogenous manures. In each series equivalent amounts of the several fertilizers were used, that is, amounts furnishing the same number of pounds of the given constituent. The percentage of potash, phosphoric acid, or nitrogen in the kinds tested was determined beforehand. Care was taken to use liberal amounts in order to allow for possible loss in their handling or application. It is known that nitrogen, phosphoric acid, and potash are more available (to the plant) in some forms than in others. In order to determine this point, as well as to check the tests of the preceding series, two amounts of each fertilizer were employed—one containing the full and the other the half dose of the given constituent.

POTASSIC MANURES.

Three kinds of potassic manures were tested—muriate of potash, containing 50 per cent of potash, sulphate of potash containing 37 per cent of potash, and kainit containing 12 per cent of potash. Equivalent amounts of each were employed. The cost of the potash in each kind will be given later on; here we are only concerned with their effects upon the crop. The full doses of phosphoric acid and nitrogen were supplied, as in the preceding series, by acid phosphate and nitrogen. These two being the constants are omitted for the sake of clearness in the statement. The effects of the full dose of potash in the three (potassic) fertilizers will first be compared.

	Pounds.
Muriate of potash	318
Sulphate of potash	322
Kainit	331

The agreement in the combined averages of the three applications is very close.

It may be objected that potash is possibly less active in some one or more of the salts and that the amount of the fertilizer used will therefore affect its results. To meet this point, equivalent amounts supplying the half dose of potash were also tested with the following results:

	Pounds.
Muriate of potash	269
Sulphate of potash	295
Kainit	332

The agreement in the combined averages is again close, for the difference between those of the kainit and the sulphate does not exceed the probable error.

It follows from these results that the three kinds may be indifferently used for supplying the required dose of potash.

These tests were also intended to check those of the preceding series. Their results were referred to under that head and it will be sufficient to give here only their combined averages.

Combined average yield of lint per acre for three years.

Fertilizer.	Muriate of potash.	Sulphate of potash.	Kainit.
	Pounds.	*Pounds.*	*Pounds.*
1 potash	318	322	331
½ potash	294	295	332

In each case the half dose was practically as effective as the full dose.

PHOSPHATIC MANURES.

Experiments with phosphatic manures are not as simple as those with potassic. Whatever may be true of potash, it is certain that some forms of phosphoric acid are more soluble, and hence more available to the plant, than others. In acid phosphate, dissolved boneblack, etc., the phosphoric acid is readily soluble; in reduced or precipitated phosphate it is slowly soluble; in basic slag, floats, coarse bones, etc., it is insoluble (in water or weak acids). Our experiments bear upon the relative values of these three classes of phosphatic manures.

Three forms of phosphoric acid are recognized by the fertilizer control stations and have different money values assigned them—the soluble, the reverted (slowly soluble), and the insoluble. The first two are generally classed together as available. There is great difference of opinion as to the relative agricultural value of these three forms. For a time it was held that to be of value to the plant phosphoric acid must be readily soluble, hence the slowly soluble form was held to be of little account. Afterwards it was discovered that the soluble form when applied to the soil was precipitated by its bases, such as alumina, iron, etc., and converted into the dicalcic or slowly soluble form, also called the reduced or reverted. Some contend that the precipitated or reverted acid is, for this reason, as available to the plant as the soluble. It is replied that the solubility of a fertilizer is largely determined by its fineness of division, and, granting that the soluble acid is immediately dissolved by the waters of the soil and precipitated, this solution and subsequent precipitation secures a thoroughness of distribution and fineness of division that can not be effected by mechanical means. The advocates of the reverted acid urge, however, that the soluble form is often taken up by the crop before it is precipitated and that its acidity is injurious to the plant. In favor of the basic or insoluble form it is asserted that it is gradually dissolved by the reagents of the soil and rendered available and that it is consequently of value to crops of comparatively slow growth. It is of interest, therefore, to collect data bearing upon these points.

All three forms of phosphoric acid were tested at the two farms. The soluble form was supplied by acid phosphate containing 16 per cent total phosphoric acid (about 11 per cent soluble, 3¼ per cent reverted, and 1¾ per cent insoluble). The reverted form was supplied by reduced phosphate. This was made by mixing acid phosphate and floats in the proportion of 2 pounds of the former to 1 pound of the latter and allowing the mixture to stand for some weeks until the soluble phosphoric acid was precipitated. The reduced phosphate contained 19.5 per cent total phosphoric acid (about 10 per cent available, the rest insoluble). The insoluble form was supplied by basic slag, containing 21.5 per cent phosphoric acid, and also by floats, containing 26.5 per cent phosphoric acid. It is claimed for the slag that its phosphoric acid is more easily rendered available by the solvents of the soil than other insoluble forms.

The acid phosphate contains, in addition to its phosphate of lime, a large amount of sulphate of lime. This sulphate sometimes acts beneficially on certain soils on account of its lime. Hence it is usual in experiments with different classes of phosphatic manures to have one or more plats dressed with plaster or sulphate of lime in order to test the relations of the soil to lime. As we had a series of tests of calcareous manures running alongside of this one which bore on this very point, sulphate of lime plats were omitted. Such amounts of the different phosphatic fertilizers were used as would supply the full dose (26 pounds) and also the half dose (13 pounds) of phosphoric acid. These were employed with full doses of potash and nitrogen. Comparing, first, the effects of the full dose of phosphoric acid in different forms, we have:

	Pounds.
Acid phosphate	318
Reduced phosphate	249
Floats	204
Basic slag	194

The two insoluble phosphates—slag and floats—gave about the same average results. As compared with their combined averages the reduced phosphate shows a gain of about 45 pounds of lint. The acid phosphate gave 69 pounds more than the reduced phosphate and 112 pounds more than the floats. It is clear that the results were directly proportionate to the solubility of the phosphoric acid—the more soluble the acid the larger the average yield of lint. The floats and slag gave no better results than acid phosphate (with soluble phosphoric acid) and potash without nitrogen, or acid phosphate and nitrogen without potash.

The half doses of phosphoric acid gave the following results:

	Pounds.
Acid phosphate	277
Reduced phosphate	205
Floats	171
Basic slag	188

The average results of the half doses agree very closely with those of the full doses. The acid phosphate shows 72 pounds more lint than the reduced phosphate and 106 pounds more than the floats.

As to the comparative effects of the full and half doses it appears that in the insoluble forms, floats and slag, one dose was about as effective as the other, both being apparently of little benefit to the crop; for allowance must be made for the nitrogen and potash with which they were combined. In the slowly soluble form, reduced phosphate, the full dose gave 44 pounds more than the half dose; in the soluble form, acid phosphate, it gave 31 pounds more than the half dose.

NITROGENOUS MANURES.

Two forms of nitrogen are recognized by agricultural chemists—organic nitrogen, contained in matters of vegetable or animal origin, such as stable manure, cotton-seed meal, dried blood, fish scrap, etc.; and inorganic nitrogen, contained in mineral matters, such as sulphate of ammonia, nitrate of soda, nitrate of potash, etc. In the following tests the inorganic nitrogen was furnished by nitrate of soda, containing 16 per cent of nitrogen, and the organic nitrogen by dried blood, containing 12½ per cent of nitrogen, cotton-seed meal containing 7 per cent of nitrogen, cotton seed containing 2½ per cent of nitrogen, and stable manure containing 0.45 per cent of nitrogen. Tests were made of both ground and unground cotton seed. Mixed nitrogen (about one half organic and one half inorganic) was furnished by a mixture of stable manure and nitrate of soda. Cotton-seed meal, cotton seed, and stable manure contain also phosphoric acid and potash. Allowance was of course made for their percentages of these two constituents. Equivalent amounts of the several fertilizers were used. Potash and phosphoric acid (full doses) were the constants.

The full dose of nitrogen in the several organic manures gave results as follows:

	Pounds.
Stable manure	392
Dried blood	358
Cotton-seed meal	312
Cotton seed (ground)	286
Cotton seed (whole)	275

The stable manure gave the best combined average and the dried blood the next best. Cotton-seed meal and cotton seed gave very nearly the same averages. The whole cotton seed gave just as good results as the ground.

The full doses of nitrogen in the inorganic, mixed, and organic forms may be compared by taking as the representative of the latter the average of the five organic manures mentioned above:

	Pounds.
Mixed nitrogen	395
Organic nitrogen	325
Inorganic nitrogen	318

The mixed nitrogen, as stated above, was furnished by stable manure and nitrate of soda, the inorganic nitrogen by nitrate of soda. This comparison favors the mixed nitrogen, and makes the other two forms show practically the same combined averages. By referring to the averages of the organic manures given above it will be seen, however, that in one kind (stable manure) organic nitrogen gave just the same results as the mixed nitrogen, and in another (dried blood) better results than inorganic nitrogen; also that in the other three kinds (cotton-seed meal, ground cotton seed, and whole cotton seed) it was about as effective as the inorganic form. It is clear that the stable manure largely affected the foregoing comparisons. Wherever used its effects were pronounced, and increasingly so from year to year. Six tons of stable manure and 3 tons of stable manure mixed with 160 pounds of nitrate of soda, both furnishing the full dose of nitrogen (together with full doses of potash and phosphoric acid), applied annually upon the same plats, greatly improved their physical properties, as will appear from the following comparisons of averages for 1888 and 1890:

At the upper farm the stable manure averaged 236 pounds for 1888 and 387 pounds for 1890; at the lower farm, 377 pounds for 1888 and 536 pounds for 1890. The mixture of stable manure and nitrate of soda gave at the upper farm 203 pounds in 1888 and 454 pounds in 1890; at the lower, 376 pounds in 1888 and 525 pounds in 1890. Its cumulative effects were marked. It is often impossible, however, for the farmer to get a sufficiency of stable manure for his entire crop. That a part of it can be fully replaced by some other nitrogenous fertilizer clearly appears from the following: Six tons of stable manure gave 392 pounds of lint per acre; 3 tons of stable manure and 160 pounds nitrate of soda, 395 pounds.

It is evident that 160 pounds of nitrate of soda were fully equal in its effects to 3 tons of stable manure. For similar reasons to those given under the last head, half doses of nitrogen were also tested, with the following results:

	Pounds.
Dried blood	364
Cotton-seed meal	343
Ground cotton seed	279
Nitrate of soda	269

The dried blood maintained its superiority. The cotton-seed meal showed somewhat better results than the ground cotton seed and nitrate of soda, which gave about the same combined averages.

Leaving out the stable manure, and in the comparison of the remaining nitrogenous fertilizers averaging the results of the full and half doses of each kind (taking it as fully established that the two doses were equally effective), their results may be finally shown as follows:

	Pounds.
Dried blood	361
Cotton-seed meal	327
Ground cotton seed	283
Nitrate of soda	293

The dried blood showed the best average results and the cotton-seed meal the next best. The ground cotton seed and nitrate of soda gave about the same averages.

It appears from the results of the tests of this series that organic nitrogen gave better results than inorganic; that of the several organic fertilizers stable manure was the best and dried blood the next best, that the difference between the cotton-seed meal and cotton seed was slight, but in favor of the meal, and that there was no difference between the ground and whole cotton seed; also that the inorganic form, in nitrate of soda, was equally as effective as the organic form in cotton seed.

The comparative effects of the full and half doses of nitrogen in the different kinds of nitrogenous manures were referred to in discussing the results of the preceding series. They may be given a little more fully here.

Combined average yield of lint per acre on the two farms for three years.

	Dried blood.	Cotton-seed meal.	Ground cotton seed.	Nitrate of soda.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Full dose	358	312	286	318
Half dose	364	343	279	269

The probable error must be allowed for. There can be no question of the equal efficacy of the half dose as compared with the full. The results strengthen the conclusions drawn from those of the preceding series, to the effect that the half, as well as the full, dose of nitrogen was excessive, and the true amount required is to be found somewhere between the quarter and half dose.

CALCAREOUS MANURES.

Although it is now held that it is only necessary to return to the soil nitrogen, phosphoric acid, and potash, yet a soil may sometimes be deficient in lime, and hence need calcareous manures. Again, some plants require considerable percentages of lime. In order to ascertain whether cotton on the soils of our farms would respond to applications of lime, and also to check our series of tests of phosphatic fertilizers, as explained above, a number of experiments were carried on at both farms, alongside of those of this series. Abundant deposits of marl, a highly calcareous manure, are found in different parts of the South. Hence it was preferred for our tests. The kind used was finely ground and contained 55.4 per cent of lime, together with 2.9 per cent phosphoric acid and a trace of potash. The dose of lime required by a crop of cotton giving 300 pounds of lint per acre is, according to the old analyses, 60 pounds. This amount was furnished by 110 pounds of marl. It was added to the full doses of nitrogen, phosphoric acid, and potash, with the following results:

	Pounds.
1 potash, 1 phosphoric acid, and 1 nitrogen	318
1 potash, 1 phosphoric acid, 1 nitrogen, and 1 lime	250

In these and several other tests made at one or other farms the marl failed to show any beneficial effect upon the crop.

It was stated that the marl contained a small percentage (2.9 per cent) of phosphoric acid. While in the number of pounds required to furnish the full or double dose of lime the amount of phosphoric acid would be insignificant, 450 pounds of marl would furnish 13 pounds of phosphoric acid or half the theoretical amount required, and 900 pounds would furnish the full dose. The phosphoric acid in marl is insoluble. In order to supplement the preceding series of experiments with phosphatic manures, by testing more fully the effects of the insoluble phosphoric acid in combination with other fertilizers and when used alone, 450 pounds of marl per acre were used at the upper farm in combination with full doses of potash, phosphoric acid (in acid phosphate), and nitrogen (in cotton-seed meal), and 900 pounds per acre were applied alone at both farms. On the upper farm the results were as follows:

Average yield of lint per acre at the upper farm for three years.

	1888.	1889.	1890.	Three years.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1 potash, 1 phosphoric acid, 1 nitrogen	276	352	307	312
Same, with addition of 450 pounds of marl	261	341	295	299

The two applications gave about the same returns. The average yields on the two farms for three years in pounds of lint per acre were as follows:

	Pounds.
Unfertilized	85
1 phosphoric acid and 8 lime (in 900 pounds of marl)	94
1 phosphoric acid (in acid phosphate)	159

The marl, containing eight times the amount of lime required by the given crop, as well as the full dose of phosphoric acid in the insoluble form, gave about the same combined average as the unfertilized plats, and much poorer returns than the full dose of soluble phosphoric acid in acid phosphate.

It appears, therefore, from the results of these tests, as well as from those of the preceding series, that insoluble phosphoric acid, whether supplied by basic slag, floats, or marl, is inferior to the soluble phosphoric acid in the acid phosphate, and of little value to cotton.

In all the foregoing tests, with a single exception, the marl was of no benefit to the crop. In the exception referred to, its beneficial effects were probably due to its action upon the organic matters of the soil. This will more clearly appear from the results of the following tests made at the lower farm. In 1888 two plats (duplicates) were dressed with 900 pounds marl each and planted in cotton. Cowpeas were drilled in between the rows at the last working given the cotton. In the fall, after the cotton was picked out, the plats were seeded in oats. In the spring of 1889 the oats were turned under, and peas were again planted without manures of any kind. In the fall the peas were plowed under and the plats were seeded in oats. In the spring of 1890 the oats were turned under and the plats were again dressed with 900 pounds of marl and put back in cotton. It is well known that calcareous manures act beneficially upon leguminous crops, such as peas, clover, etc. It was expected of this test, first, that the heavy dressing of marl would greatly improve the several crops of peas and, therefore, aid in supplying a large amount of vegetable matter to the soil and at the same time hasten its decomposition; and second, that this vegetable matter would, in its turn, cheaply furnish nitrogen to the cotton crop, and improve the physical properties of the soil. It will be noticed that marl was the only fertilizer used, that the plats were in peas without cotton in 1889 and unmanured, and that when planted in cotton in 1888 and 1890 each received 900 pounds of marl per acre. It will be interesting to compare the results with some already noticed.

Average yields of lint per acre at the lower farm in 1890.

	Pounds.
Unfertilized (in cotton in 1888 and 1889, unfertilized each year)	86
900 pounds of marl (in cotton in 1888 and 1889, with 900 pounds marl each year)	71
Full doses of nitrogen, phosphoric acid, and potash (1888 and 1889—same crop and fertilizers)	392
900 pounds of marl (1888 cotton with 900 pounds marl; 1889 peas only unfertilized)	364

The figures are surprising. While the marl used alone was clearly of no value to the cotton, in connection with the vegetable matter of the peas and oats it increased the yield more than tenfold, and gave returns nearly equal to those of the full doses of nitrogen, phosphoric acid, and potash.

The tests of this series go to show that lime in marl, whether used n small or large doses, is of little value to cotton in the absence of organic matter, but that where this is present it acts beneficially; also that it can be used with decided advantage upon the pea crop.

EFFECTS OF COPPERAS.

Articles have been repeatedly published in Southern agricultural journals asserting that copperas would prevent the rusting of cotton. Such claims are opposed to the opinion generally held that sulphate of iron (copperas) acts injuriously in the soil. In order to test them, different amounts of copperas were applied each year with full doses of nitrogen, phosphoric acid, and potash, with the following results:

	Pounds.
Without copperas	318
With 100 pounds of copperas	283
With 50 pounds of copperas	307

It is evident the copperas produced no effect, either beneficial or injurious, upon the crop.

THE BEST TIME FOR APPLYING NITRATE OF SODA.

There is considerable difference of opinion as to the best time for applying nitrate of soda. It can, of course, be most economically applied with the other fertilizers at the time of planting. It is objected to this, that there is danger of the nitrate being washed out of the soil by heavy spring rains before the crop is sufficiently advanced to assimilate it. Others hold that it can be more effectively applied in one or more top-dressings. A number of experiments bearing upon this question were begun at the lower farm in 1889. The full doses of potash and phosphoric acid were in every case used with the nitrate of soda.

Nitrate of soda containing the full dose of nitrogen was applied at different times, as follows: All at time of planting; half at planting and half in one top-dressing; all in one top dressing; all in two equal top-dressings. From the results of the tests it appeared that nitrate of soda can be applied as effectively, and certainly more economically, with the other fertilizers at the time of planting, as it can in one or more top-dressings.

METHODS OF APPLYING FERTILIZERS.

In the South the fertilizers used on cotton are generally applied in the hill or drill before or at the time of planting. Whether drilling will, under all circumstances, give better results than broadcasting is a question not yet decided. Our tests bore upon it. Applications containing both the full and half doses of nitrogen, with full doses of potash and phosphoric acid, were tested at both farms. The nitrogen was furnished by cotton-seed meal. The applications containing the full dose gave results as follows:

	Pounds.
In hill	312
Broadcast	303

It is evident that the two applications gave about the same results.

The applications containing the half dose of nitrogen gave results as follows:

	Pounds.
In hill	343
Broadcast	245

The difference in favor of drilling amounted to about 100 pounds of lint per acre at each farm.

Other combinations of fertilizers were tested in the same way at the lower farm. The results showed that where liberal amounts of fertilizers were used one method was certainly as effective as the other, but where smaller amounts were employed the tests appeared to favor drilling.

THEORETICAL AND ACTUAL YIELD OF LINT PER ACRE.

It has been explained that our applications, when full doses were used, supplied the amount of potash, phosphoric acid, and nitrogen contained in a crop of cotton yielding 300 pounds of lint per acre. According to the old analyses and determinations, which we were obliged to fall back upon, this crop is made up as follows: Lint 300 pounds, seed 600 pounds, leaves 500 pounds, bolls 500 pounds, stems 1,200 pounds, roots 300 pounds; total 3,400 pounds, containing 52 pounds of nitrogen, 48 pounds of potash, and 26 pounds, of phosphoric acid. Determinations and analyses made by our assistant chemist, J. B. McBryde, continued for two years and carefully duplicated and checked each season, showed the above figures to be inaccurate, and that the crop is made up of 300 pounds of lint, 654 pounds of seed, 404 pounds of leaves, 575 pounds of bolls, 658 pounds of stems, and 250 pounds of roots; total 2,841 pounds, containing 46 pounds of nitrogen, 39 pounds of potash, and 12 pounds of phosphoric acid. The two series differ widely in their amounts of stems and phosphoric acid. In other respects, the agreement between them is reasonably close.

The table giving the results of our analyses and determinations is of such value in the present connection as to call for its insertion here. It was first given to the public in a bulletin of the experiment station of the University of Tennessee entitled A Chemical Study of the Cotton Plant.

Fertilizing constituents contained in a crop of cotton yielding 300 pounds of lint per acre.

Fertilizing constituents (calculated).	Pounds per acre.						
	In 300 pounds lint.	In 654 pounds seed.	In 404 pounds bolls.	In 575 pounds leaves.	In 658 pounds stems.	In 250 pounds roots.	In 2,841 pounds total crop.
Nitrogen	0.72	20.08	4.50	13.85	5.17	1.62	45.94
Phosphoric acid, P_2O_5	0.18	6.66	1.14	2.57	1.22	0.38	12.15
Potash, K_2O	2.22	7.63	12.20	6.57	7.74	2.75	39.11
Soda, Na_2O	0.08	0.12	0.19	1.61	0.65	0.38	3.03
Lime, CaO	0.46	1.22	3.75	31.57	5.59	1.36	43.95
Magnesia, MgO	0.41	3.26	1.01	5.73	2.43	0.80	13.64
Sulphuric acid, SO_3	0.26	0.84	1.75	3.38	0.74	0.28	7.25
Insoluble matter	0.08	0.15	1.14	6.43	0.89	0.55	9.24

Confining our attention for the present to the old analyses, it will be of interest to inquire as to the correspondence between the expected and actual results of the applications. As already stated, after examining the soils of the two farms and inquiring into their history, we assumed that they would produce, without manures of any kind, about 50 pounds of lint per acre. It will be seen from the figures that they gave somewhat better results than this, their average produce of lint for the three years amounting to 74 pounds at the upper farm and 96 pounds at the lower, or an average of 85 pounds for the two farms. The full applications furnished amounts of the three constituents sufficient, theoretically, to produce 300 pounds of lint per acre. Hence, the crops should have averaged for the three years 374 pounds of lint at the upper farm and 396 pounds at the lower, or 385 pounds for the two farms.

It will be remembered that mixed nitrogen in stable manures and nitrate of soda, and organic nitrogen in stable manure, and dried blood, gave the best averages. Their results may be compared with the above figures as follows:

	Pounds.
Expected crop	385
Stable manure and nitrate of soda	395
Stable manure	392
Dried blood	385

Two of the applications actually gave the expected averages at both farms, and the third gave it at the lower.

It has already been observed that either increasing the amount of nitrogen or potash by as much as 100 per cent or decreasing it by 50 per cent was without effect upon the crop, but that it quickly responded to any change in the soluble phosphoric acid. By way of additional confirmation of this statement, and in order to show the difference between the expected and actual results of the several applications of commercial fertilizers, it may be well to submit a few more comparisons. Excluding, therefore, the stable manure and cotton seed, the average of the applications containing the full doses of the three constituents (the phosphoric acid in soluble form), the average of those containing half doses of potash or nitrogen together with full doses of the other constituent and of soluble phosphoric acid, and the averages of those containing double doses of potash or nitrogen, together with the full dose of soluble phosphoric acid and the full or double dose of the other constituent, may be compared as follows:

	Pounds.
Expected crop	385
Average of full dose of three constituents	328
Average half dose of nitrogen or potash	316
Average of double doses of nitrogen or potash or both	289

It will be noticed that the three averages fell considerably below the expected or theoretical crop.

The average of the several applications containing double doses of soluble phosphoric acid, together with full doses of the other two constituents, or the full dose of one and double dose of the other, corresponded almost exactly, on the other hand, with the theoretical average, as appears from the following:

	Pounds.
Expected crop	385
Average of double dose of soluble phosphoric acid	386

The agreement between the combined averages is perfect.

It is known that fertilizers produce their full effects only in good seasons. The tests showed that 1889 was the most favorable of the three seasons at the upper farm, and 1890 the most favorable at the lower farm. It may be asked, How would the comparisons of the actual and expected results stand for those years? It is noteworthy that the unfertilized plats averaged 86 pounds of lint per acre at the upper farm in 1889, and the same number of pounds at the lower in 1890. The several applications were therefore expected to show 386 pounds of lint per acre at each farm for the years named. Comparing with this five of the applications containing full doses of nitrogen, phosphoric acid, and potash, we have:

Average yields of lint per acre on two farms.

	Upper farm, 1889.	Lower farm, 1890.
	Pounds.	*Pounds.*
Expected crop	386	386
Dried blood	366	410
Nitrate of soda	348	392
Cotton-seed meal	352	355
Kainit	371	406
Sulphate of potash	360	375

Whether we consider the correspondence between the assumed and actual yields, between the results of the same applications at the two farms, or between the results of the several applications at each farm, the agreement in the figures is surprising—closer could not be expected in work of this kind. In no case does the difference exceed the probable error.

CONCLUSIONS.

Carefully studied in all their bearings the results of our tests of fertilizers warrant the following general conclusions:

(1) Cotton requires nitrogen, phosphoric acid, and potash.

(2) Of the three, phosphoric acid is relatively the most important and controls the action of the other two. It can be used alone with some advantage to the crop, but much more effectively in connection with potash and nitrogen.

(3) Nitrogen is relatively more important than potash. It can only be advantageously used in combination with phosphoric acid, or phosphoric acid and potash.

(4) Potash, like nitrogen, is of little value to cotton when applied separately; it must be combined with the other constituents.

(5) Expressed in terms of the old analyses the proportion and amounts of nitrogen, phosphoric acid, and potash required, are as follows:

Between one fourth and one half nitrogen, about 2 phosphoric acid, between one fourth and two fifths potash.

Or, stated in terms of our later and corrected analyses:

Between three sevenths and four sevenths nitrogen, about 4¼ phosphoric acid, between one third and one half potash.

With proper allowance for the cost as well as the effect of each application, the requirements may be more exactly given as follows: 0.43 nitrogen, 4.16 phosphoric acid, 0.38 potash. In other words, the required proportion is, 1 nitrogen, 2¼ phosphoric acid, and ¾ potash, and the amounts called for by a crop yielding 300 pounds of lint per acre are, nitrogen 20 pounds, phosphoric acid 50 pounds, and potash 15 pounds.

(6) The amount of phosphoric acid determines the amount of nitrogen and potash; with a given amount of the first, only certain amounts of the last two can be profitably used.

(7) The amount of phosphoric acid and proportionate amounts of nitrogen and potash can not be indefinitely increased with the expectation of obtaining a corresponding increase in the crop. The gain in crop does not keep pace with increase of fertilizers, and a point is speedily reached beyond which this gain is not sufficient to meet the additional cost of the heavier applications. The soil can not be profitably forced; the application of fertilizers must be regulated by its mechanical as well as chemical condition.

(8) Potash can be as effectively supplied by muriate of potash or kainit as it can by sulphate of potash. This is opposed to the view which regards the chlorides of the two former as injurious, and therefore holds that the higher priced potash of the latter is to be preferred. Since equivalent amounts of potash in the three kinds are of equal value to cotton, the choice of the farmer must be determined by their relative cost. At present prices, and especially when the matter of freight is considered, the potash of the muriate is the cheapest.

(9) Phosphoric acid is of value to cotton in proportion to its solubility; hence the several kinds of phosphatic manures can not be indifferently employed. Preference must be given to acid phosphates containing considerable percentages of soluble phosphoric acid. Insoluble phosphoric acid in slag, floats, or marl is of little direct value to the crop upon which it is applied, and even granting that its effects in the soil may be lasting, they are not, in the long run, sufficiently pronounced to meet the interest on the capital invested in the application. Speculating in futures is not a safe business. According to the best agricultural experience of our day, the better plan is to use only such fertilizers as will meet the demands of the crop upon which they are applied.

(10) Inorganic, organic, and mixed nitrogen are of very nearly equal value to cotton. The slight difference is in favor of the last two. Stable manure containing organic nitrogen is the best fertilizer of its class, and is lasting or cumulative in its effects. The organic nitrogen of stable manure to the amount of 50 per cent can be fully replaced by the inorganic nitrogen of nitrate of soda.

Of the commercial forms of nitrogen, among which the farmer has to choose, the organic nitrogen of dried blood is perhaps the best, and at present prices the cheapest. As between cotton-seed meal and cotton seed there is a slight difference in favor of the former. Whole cotton seed is as efficacious as ground cotton seed. Inorganic nitrogen in nitrate of soda is about as valuable to cotton as organic nitrogen in cotton seed or cotton-seed meal.

(11) Used alone or in combination with commercial fertilizers the lime of marl is of no direct value to cotton. Mixed with acid phosphate it may even act injuriously by retarding or preventing its solution in the soils. Applied upon leguminous crops, such as cowpeas, vetch, etc., which are to be turned under as a preparation for cotton, its indirect value is great.

(12) Applications of copperas are without effect upon cotton.

(13) Nitrate of soda should generally be applied with the other fertilizers at the time of planting.

(14) Fertilizers may be indifferently drilled or broadcasted where they are liberally applied, but drilling is to be preferred where small amounts are employed.

(15) The foregoing conclusions of course apply only to soils similar in character and condition to those tested at our two farms. Of these the lower was light and sandy; the upper contained a considerable percentage of clay. Both were quite thin. They fairly represented, therefore, large and different classes of Southern soils. When it is also stated that the seasons of the three years varied greatly and that the results of the corresponding tests closely agreed at the two farms, it follows that the conclusions admit of fairly wide application.

PRACTICAL APPLICATIONS.

It may be asked by the farmer, How can the required amounts of nitrogen, phosphoric acid, and potash be supplied? Suppose the choice of materials to be limited—that only cotton seed, kainit, or stable manure can be obtained. The following tabular statements will furnish useful guidance in the work of preparing composts or mixing fertilizers. The first gives the average percentages of nitrogen, phosphoric acid, and potash in different fertilizing materials.

Average percentages of nitrogen, phosphoric acid, and potash in different fertilizers.

Fertilizer.	Nitrogen.	Phosphoric acid.	Potash.
	Per cent.	*Per cent.*	*Per cent.*
Sulphate of ammonia	20.50		
Nitrate of soda	15.75		
Dried blood	12.00		
Cotton-seed meal	7.00	2.75	1.75
Cotton seed	2.50	1.30	1.20
Stable manure	0.45	0.25	0.40
Dissolved boneblack		18.00	
Acid phosphate		15.00	
Basic slag		21.50	
Floats		26.50	
Acid phosphate (with potash)		13.50	1.75
Cotton-seed hull ashes		9·00	22.50
Wood ashes		1.75	6.00
Muriate of potash			50.00
Sulphate of potash			37.00
Kainit			12.00

The figures represent, in each case, the averages of many analyses. Suppose it is wished to use nitrate of soda. It contains, according to the tabular statement, 15¾ per cent of nitrogen, and it will be found, by a very simple calculation, that 127 pounds will furnish the required dose of nitrogen, 20 pounds. If cotton-seed meal is preferred, a similar calculation will show that 285 pounds will give the required amount of nitrogen, and also 7.8 pounds of phosphoric acid and 4.9 pounds of potash. According to the above percentages the remainder of the phosphoric acid and potash required can be supplied by 281 pounds of acid phosphate and 92 pounds of kainit.

The number of pounds of nitrogen, phosphoric acid, and potash required by a crop of cotton yielding 300 pounds of lint per acre, are supplied by each of the following formulas:

Formulas required by cotton.

1	Muriate of potash	pounds	30
	Acid phosphate (16 per cent of phosphoric acid)	do.	312
	Nitrate of soda (16 per cent of nitrogen)	do.	125
2	Muriate of potash	do.	30
	Acid phosphate (15 per cent of phosphoric acid)	do.	334
	Dried blood	do.	167
3	Muriate of potash	do.	20
	Acid phosphate (15 per cent of phosphoric acid)	do.	281
	Cotton-seed meal	do.	286
4	Muriate of potash	do.	10
	Acid phosphate (with potash)	do.	312
	Cotton-seed meal	do.	286
5	Cotton-seed hull ashes	do.	45
	Acid, phosphate (15 per cent of phosphoric acid)	do.	261
	Cotton-seed meal	do.	286
6	Wood ashes (unleached)	do.	167
	Acid phosphate (15 per cent of phosphoric acid)	do.	261
	Cotton-seed meal	do.	286
7	Kainit	do.	58
	Acid phosphate (15 per cent of phosphoric acid)	do.	300
	Nitrate of soda	do.	70
	Stable manure	ton	1
8	Muriate of potash	pounds	20
	Acid phosphate (15 per cent of phosphoric acid)	do.	300
	Nitrate of soda	do.	64
	Cotton seed	bushels	23⅓
9	Kainit	pounds	64
	Acid phosphate (15 per cent of phosphoric acid)	do.	273
	Cotton-seed meal	do.	143
	Cotton seed	bushels	13⅓
10	Kainit	pounds	45
	Acid phosphate (15 per cent of phosphoric acid)	do.	264
	Cotton seed	bushels	26⅔
11	Acid phosphate (15 per cent of phosphoric acid)	pounds	266
	Nitrate of soda	do.	13
	Stable manure	tons	2
12	Ammoniated acid phosphate with potash, containing, nitrogen, 4 per cent (equal to 4.85 per cent ammonia); phosphoric acid, 10 per cent (nearly all available); and potash, 3 per cent	pounds	500

No. 1 is the formula used in our tests. The materials cost about $4.50. Where commercial fertilizers are employed No. 2 will give the best results. Cost, about $4.25.

When dried blood can not be obtained it can be replaced by cotton-seed meal, as in No. 3. Cost, about $4.70.

According to the late reports of State chemists, the acid phosphates offered for sale in our markets contain, on the average, 15 per cent of total phosphoric acid. There is, unfortunately, some confusion in the nomenclature of the phosphates. The term *acid phosphate* is applied by some manufacturers to dissolved phosphatic rock containing small percentages of potash. Without the potash the fertilizer is indifferently called dissolved bones, superphosphate of lime, acidulated rock, etc. At the North the last kinds are called plain superphosphates, or acid phosphates—a better term.

It is sometimes difficult to get the plain acid phosphate—that is, an acid phosphate without potash. In this case No. 4 should be used.

In the neighborhood of the oil mills cotton-seed hull ashes can often be bought at moderate prices and may be advantageously substituted, as in No. 5, for the muriate of potash in No. 3. Cost, about $4.75.

When the wood ashes of the household fires are carefully saved, they may in turn replace the cotton-seed hull ashes, as in No. 6, and reduce the cost to $4.30.

In No. 7 half the required amount of nitrogen is furnished by nitrate of soda and half by stable manure, and the potash chiefly by kainit. It will be remembered that mixed nitrogen gave excellent results. The materials, exclusive of the stable manure, will cost about $3.25.

In No. 8 the potash is supplied by muriate of potash, and the stable manure is replaced by cotton seed. The cost, exclusive of the cotton seed, is about $3.05.

In No. 9 kainit replaces the muriate of potash in No. 8, and cotton-seed meal the nitrate of soda. Cost, exclusive of the cotton seed, about $3.25.

No. 10 may be used when there is an abundance of cotton seed. Excluding the cotton seed, the other materials will cost about $1.70.

If, on the other hand, the supply of stable manure is abundant, No. 11 may be used with advantage. The materials, exclusive of the stable manure, will cost about $1.70.

If it is desired to use a manufactured article, one containing the percentages of No. 12 should be ordered.

FARMERS' BULLETINS.

The bulletins of this series may be obtained by applying to the Secretary of Agriculture, Washington, D. C. The following have been previously issued:

Farmers' Bulletin No. 1. The What and Why of Agricultural Experiment Stations. (A brief explanation of the object, origin, and development of the stations, their work in Europe and in the United States, and the operations of the Office of Experiment Stations of the Department of Agriculture.) Pp. 16. Issued June, 1889.

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 15.

AGRICULTURAL EXPERIMENT STATION,
FEB 11 1898
UNIVERSITY OF ILLINOIS.

SOME DESTRUCTIVE POTATO DISEASES:

WHAT THEY ARE AND HOW TO PREVENT THEM.

BY

B. T. GALLOWAY,
Chief of the Division of Vegetable Pathology.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

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Farmers' Bulletin No. 14. Fertilizers for Cotton. By J. M. McBryde, Ph. D., President of Virginia Agricultural and Mechanical College. Pp. 32. Issued March, 1894.

SOME DESTRUCTIVE POTATO DISEASES: WHAT THEY ARE AND HOW TO PREVENT THEM.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Vegetable Pathology,
Washington, D. C., March 9, 1894.

Sir: I have the honor to submit herewith the manuscript of Farmers' Bulletin No. 15, on some destructive potato diseases and methods of treating the same.

Respectfully,

B. T. Galloway,
Chief of Division of Vegetable Pathology.

Hon. J. Sterling Morton,
Secretary of Agriculture.

INTRODUCTION.

Among the many fungous diseases affecting the Irish potato, three are especially worthy of consideration, on account of the regularity of their occurrence in the United States and the widespread losses they occasion. The diseases in question are potato blight or downy mildew, the Macrosporium disease, and potato scab. In the accompanying pages are given some of the more important characters, by means of which the several diseases may be distinguished, together with brief directions embodying the latest information in regard to treatment.

HOW THE DISEASES MAY BE DISTINGUISHED.

Potato blight (*Phytophthora infestans*).—This disease attacks the leaves, stems, and tubers. Generally the first noticeable effect upon the leaves is the sudden appearance of brownish or blackish areas, which soon become soft and foul-smelling. So sudden is the appearance of the disease in some cases that fields which one day look green and healthy may within the next day or two become blackened as though swept by fire. The rapid spread of the disease is dependent in large measure upon certain conditions of moisture and heat. A daily mean or normal temperature of from 72° to 74° F. for any considerable time, accompanied by moist weather, furnishes the best conditions for the spread of the disease. On the other hand, if the daily mean or normal temperature exceeds 77° for a few days the development of the disease is checked. This fact explains why the potato-blight fungus seldom occurs to any serious extent in sections where the mean or normal daily temperature exceeds for any length of time 77°. The tubers affected with the disease in question show depressed, dark-colored spots on the surface, while within are seen blotches and streaks of a brownish or blackish color. Other diseases may produce similar effects, so that in this case the changes are not so characteristic as those shown by the leaves.

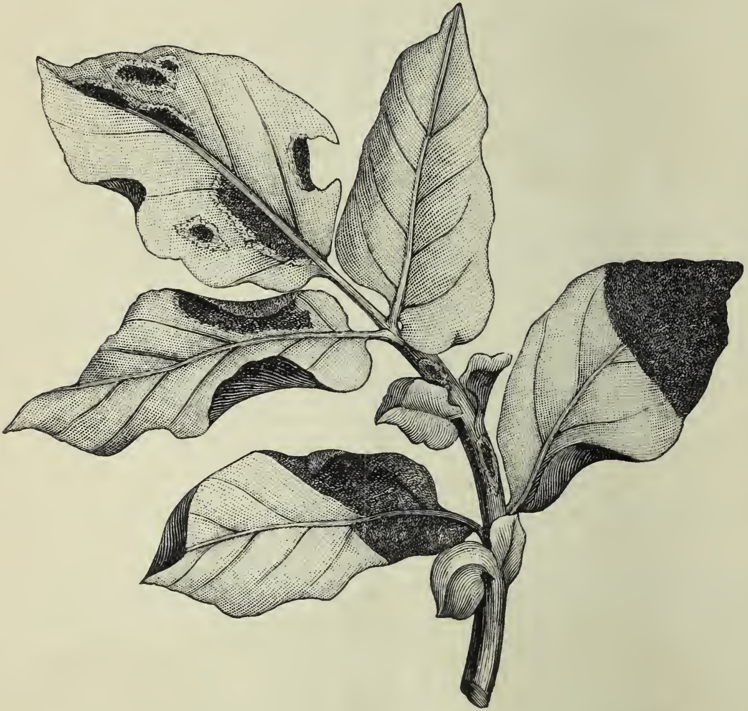

Fig. 1.—Leaf of potato affected with blight (*Phytophthora infestans*).

The Macrosporium potato disease.—From reliable evidence there is every reason to believe that this disease is often more widespread and destructive in this country than the true blight. There is no doubt that the two diseases are often mistaken for the same thing; in fact it has been the custom for many years to attribute nearly all maladies affecting the potato to the blight fungus.

The Macrosporium disease (fig. 2) attacks the leaves and sometimes the stems, but never the tubers. The disease may appear at any time after the plants are from 4 to 6 inches high. At first the older leaves show grayish brown spots, the affected parts becoming hard and brittle. The disease progresses rather slowly, the spots gradually becoming larger, especially along the edges of the leaflets. At the end of ten days or two weeks half of the leaf surface may be brown, withered, and brittle, while the rest is of a pale yellow color. Three weeks or a month may elapse before all the leaves succumb, the stems in the meantime remaining green, until they finally perish through lack of nourishment. The tubers stop growing almost as soon as the leaves are attacked, and as a result the crop is practically worthless.

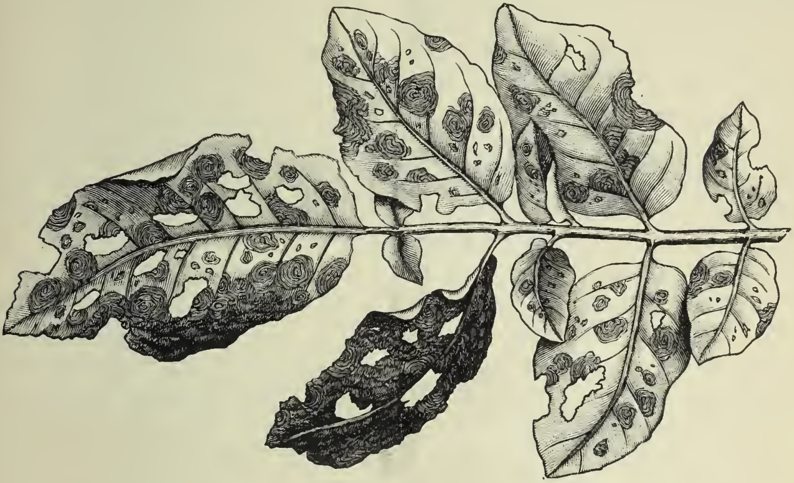

FIG. 2.—Leaf of potato affected with the Macrosporium disease.

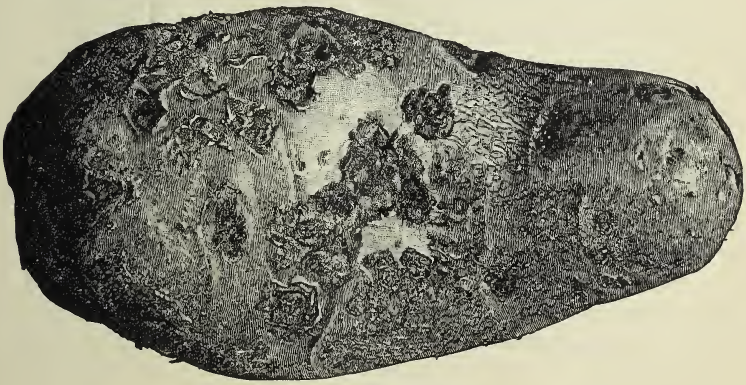

FIG. 3 —Potato scab.

Potato scab.—Within recent years this disease has attracted a great deal of attention. Its effects on the tuber are so prominent and easily recognized that nothing further on this point need be said (fig. 3).

FUNGICIDES OR PREVENTIVES TO BE USED FOR THE DISEASES.

For blight and the Macrosporium disease nothing so effective as the Bordeaux mixture has been found. This should be prepared as follows: Pour into a 45-gallon barrel about 30 gallons of clean water, then weigh out 6 pounds of bluestone or copper sulphate, and after tying it in a piece of coarse sacking, suspend the package just beneath the surface of the water by means of a string tied to a stick laid across the top of the barrel. In another suitable vessel, such as a tub or half barrel, slack 4 pounds of fresh lime. Slack the lime carefully by pouring on small quantities of water at a time, the object being to obtain a smooth, creamy liquid, free from grit. As soon as the bluestone is dissolved, which will require probably less than an hour, pour the lime milk into the bluestone solution, stirring constantly to effect a thorough mixing; add enough water to fill the barrel, stir again, and the mixture is then ready for use.

For the treatment of potato scab a solution of corrosive sublimate has given the best results. This should be prepared by dissolving 2¼ ounces of corrosive sublimate in about 2 gallons of hot water and after an interval of ten or twelve hours diluting with 13 gallons of water.

WHEN AND HOW TO APPLY THE FUNGICIDES.

For potato blight and the Macrosporium disease, apply the Bordeaux mixture, beginning when the plants are about 6 inches high, and continuing at intervals of twelve or fourteen days, until five or six applications in all have been made. If the season is rainy it would probably be best to make the treatments every ten days, the object being to *keep the plants at all times covered with the fungicide.* By adding 4 ounces of Paris green to each barrel of the Bordeaux mixture the treatments will not only prevent the diseases under consideration, but keep in check the Colorado potato beetle and other insects as well. Before adding the Paris green to the Bordeaux mixture the former should be made into a thin paste by mixing with a small quantity of water.

The success of this work depends in large measure upon the thoroughness with which the fungicides are applied. To reach all parts of the plants above ground with a fine spray requires a good force pump and a suitable nozzle. The knapsack sprayer now on sale in nearly every section of the country will be found one of the most useful machines for spraying fields of 5 acres or less. For larger plantations more powerful machines should be used. A cheap and serviceable apparatus, well suited for this work, may be made by mounting a good, strong force pump on a barrel and then placing the barrel and mounted pump in a light wagon. The entire outfit, including barrel, pump, hose, nozzles, operator, and boy to drive, may be drawn by one horse. As the wagon is drawn slowly between the rows the man in the wagon may operate the pump, and at the same time keep the mixture stirred, while two others on the ground hold the nozzles and direct the spray over the plants. The nozzle found best suited to the work is the Vermorel; this is now offered for sale by pump manufacturers and dealers in seeds and agricultural implements in various parts of the country. Of course where there are only a few plants to treat simple devices for the application of the fungicide, such as syringes, watering cans, and even old brooms may be used. These makeshifts, however, should be avoided as much as possible, as they not only fail to distribute the mixture uniformly, but are wasteful.

In addition to the line of treatment suggested care must be taken to avoid the use of diseased "seed," and further, the stems and leaves killed by either the blight or Macrosporium disease should be mowed or cut off and burned.

Potato scab has been very successfully prevented by the use of the corrosive sublimate solution already described, very smooth potatoes having been grown from very scabby tubers. The potatoes to be planted are simply immersed in the solution for an hour and a half, then spread out to dry, cut, and planted in the usual manner. A large barrel offers a convenient receptacle for the solution. The potatoes may be placed in a coarse sack and suspended in the liquid, care being taken to wash the tubers before dipping, providing they are very dirty. The corrosive sublimate is very poisonous, therefore it must be used with great care and kept out of the reach of children and animals. *All treated tubers should be planted.*

COST OF THE WORK.

The cost of the work outlined for potato blight and the Macrosporium disease will depend to a considerable extent upon the kind of machinery used and the price paid for labor. With suitable apparatus, such as has been described, and labor estimated at $1.50 per day, potatoes may be sprayed six times for about $6 per acre. This estimate is based upon experiments extending over several years, and includes the cost of chemicals as well as of labor. The cost of treating scab is mainly in the labor involved in dipping and drying the seed and seldom exceeds 15 cents per acre.

CONCLUSIONS.

The three diseases discussed cause a loss in this country of several million dollars annually. It is believed that much of this loss may be prevented by following the suggestions made, but it must be borne in mind that the treatments are preventive, not curative. The importance, therefore, of beginning the work in time can not be too strongly urged. In the case of blight and the Macrosporium disease the question may arise as to the advisability of going to the expense of arranging for work that may not be necessary on account of the diseases not appearing. In answer to such a question it may be said that there is scarcely a section of the country where one or another of the diseases mentioned does not occur every year. Furthermore, it is a fact well established by experiments that, even if no diseases whatever appear, spraying with the Bordeaux mixture will increase the yield to such an extent as to make the work profitable.

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FARMERS' BULLETIN No. 16.

LEGUMINOUS PLANTS

FOR

GREEN MANURING AND FOR FEEDING.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., March 30, 1894.

Sir: I have the honor to transmit herewith for publication as a Farmers' Bulletin an article on the value and use of leguminous plants for green manuring and for feeding, prepared under my direction by E. W. Allen, PH. D., assistant director of this Office. The scientific investigations in this country and abroad on the assimilation of nitrogen of the air by leguminous plants and the practical experiments with numerous varieties of these plants in the fields and in the stables of experiment stations, as well as by progressive farmers, have more definitely established the importance of these crops in maintaining or increasing the fertility of our agricultural lands and in providing our live stock with well-balanced rations. The résumé of this subject from the standpoint of advanced theory and practice, which this article contains, can in my judgment be usefully distributed in all sections of our country.

Respectfully,

A. C. True,
Director.

Hon. J. Sterling Morton,
Secretary of Agriculture.

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LEGUMINOUS PLANTS FOR GREEN MANURING AND FOR FEEDING.

GREEN MANURING.

Green manuring, or plowing under green crops raised for that purpose, is one of the oldest means of improving the fertility of the soil. It was advocated by Roman writers more than two thousand years ago, and from that time until now it has formed a most important resource of the farmer, especially where the supply of barnyard manure is insufficient. Its advantages are many. The more striking are that it furnishes the surface soil with a supply of the fertilizing materials needed by crops, increases the humus, and improves the physical qualities and the tilth of the soil. As a humus-former green manuring stands next to barnyard manure.

By means of green manuring, land which is practically barren may be brought up to a state of fertility where it will produce profitable crops. As a single instance of this may be mentioned the experiments carried on by the Michigan Experiment Station on the "Jack-pine plains" of that State. In 1888 experiments were undertaken on the light sandy, almost barren, soils of these plains. Green manures were used mainly, supplemented by cheap fertilizers. In three years marked improvement was evident, not only in the physical character of the soil, but also in the increased yields of various crops.

Again, green manuring may be used to take the place of more expensive fertilizers and manures on soils already under cultivation. It is in this latter use that it finds its widest application.

There has been much speculation as to the manner in which the crops commonly used for green manuring could gather such large quantities of fertilizing materials. It will be remembered that the principal fertilizing ingredients required by plants are nitrogen, phosphoric acid, and potash. These are each and all more or less essential to the healthy growth of crops. Consequently they are applied to the soil in the form of commercial fertilizers and other manures. In attempting to explain how the fertility of the soil is maintained by green manuring it has been said that plants with long roots, like clovers, feed deep down in the soil or subsoil on materials beyond the reach of surface-feeding plants; and that when the tops of these plants die down and are mixed with the surface soil they enrich it much the same as an application of barnyard manure. This is undoubtedly true, but it fails to explain how such large quantities of materials can be obtained, especially when clover is grown continuously for a number of years. The question has finally been solved by one of the most interesting and important discoveries yet made in agricultural science. It has been found that certain plants can feed upon the nitrogen in the atmosphere and store it up in their tissues as they grow. They take their phosphoric acid and potash from the soil, but they obtain their nitrogen very largely from the air. Hence they draw from the air a material necessary to the growth of crops, which in the form of commercial fertilizers, as nitrate of soda, ammonium sulphate, dried blood, etc., is paid for at the rate of from 15 to 20 cents a pound.

HOW PLANTS GET NITROGEN FROM THE AIR.

The air we breathe is about four fifths nitrogen and one fifth oxygen. We use the oxygen in breathing but discard the nitrogen. It has been regarded merely as a material for diluting the oxygen, which would otherwise be too strong for our use. All attempts to economically render this nitrogen of the air available for plant food, by chemical means, have been unsuccessful. Recently it has been discovered that the so-called leguminous plants—clovers, peas, beans, lupines, vetches, etc.—can take up this nitrogen of the air, and can grow without being manured with nitrogen if manured with phosphoric acid and potash.

The manner in which this nitrogen assimilation takes place has been carefully and patiently studied by scientists, and although the details are not fully understood the primary cause has been found. It is believed that plants are enabled to get this nitrogen through the activity of the lower forms of life, bacteria or microbes, which can only be seen with the aid of a powerful microscope. These organisms live in the soil and are to be found where leguminous plants have been grown. They produce or cause the plant to produce little nodules, or tubercles, on the roots. It is through these tubercles that the plant gets its atmospheric nitrogen. The air enters the soil by the numerous pores or openings in it, which are produced by plowing, cultivating, and working the soil, by the decay of rootlets, by earthworms, etc. By just what physiological processes the nitrogen assimilation takes place is a question still in dispute among scientists. It is sufficient for practical purposes to know that nitrogen is taken up from the air by the growing plant, directly or indirectly; and that this nitrogen assimilation takes place as a result of the life of bacteria. It is a peculiar fact that few, if any, root tubercles are formed when leguminous plants are manured with nitrogen; the plants must first hunger for nitrogen before the tubercles are formed, and the presence of tubercles indicates that the plant is taking nitrogen from the air.

Now, curious as it may seem, there appear to be different forms of bacteria for different kinds of plants. Hence it sometimes becomes necessary to provide crops with the necessary bacteria before they can use the nitrogen of the air. This is done by applying a light dressing of soil in which the kind of plants it is wished to grow have been previously grown. This is called soil inoculation. It is sometimes necessary in growing a crop on a piece of land for the first time in several years. Suppose, for instance, that peas which had been sown on land manured with phosphates and potash but without nitrogen failed to grow luxuriantly. If the other conditions were favorable, the inference would be that bacteria of the right kind were lacking in the soil, and a light dressing of soil in which peas had previously been successfully grown might be applied. Such treatment as this has been repeatedly tried with success on a large scale.

These discoveries throw a new light on green manuring and on the plants best adapted for green manuring. They recommend it more highly than ever before as a soil renovator and a cheap means of maintaining the fertility of a soil. They show that while both leguminous and non-leguminous plants enrich the soil alike in humus-forming materials, in proportion to the size of the crop, they differ in respect to the source of their nitrogenous materials. While non-leguminous plants derive their nitrogen supply almost exclusively from the soil, leguminous plants may take theirs largely from the air. Consequently, if spurry, buckwheat, mustard, etc. (non-leguminous plants), are grown on the soil and the crop plowed in, the soil is not materially enriched in nitrogen; the process is simply returning to the soil all the nitrogen which the crop took from it. But since leguminous plants may derive the larger proportion of their nitrogen from without the soil—that is, from the air—their use for green manuring actually enriches the soil in nitrogenous matter.

It will thus be seen that by green manuring with leguminous crops it is possible to manure the soil with nitrogen from the air, a free and inexhaustible source, and thus avoid buying fertilizers containing much nitrogen. This greatly lessens the expense for commercial fertilizers, for nitrogen is the most expensive element the farmer has to buy. As stated above, it costs from 15 to 20 cents a pound, while potash and phosphoric acid cost only 5 to 7 cents, or even less. Although grains, grasses, corn, cotton, root crops, tobacco, etc., can not use the nitrogen of the air, green manuring enables them to benefit by it indirectly.

SOME CROPS FOR GREEN MANURING.

Among the leguminous plants more commonly used for green manuring in this country and in Europe are cowpea, alfalfa, clovers, melilotus, serradella, lupines, vetch, and horse bean. Some of these are described below.

COWPEA.

The cowpea is widely used as a green manure in the Southern States. According to the North Carolina Experiment Station, "the cowpea, being a tender annual, should always be sown in the spring. It will give a good yield sown as late as July 1, but the earlier it is sown after danger of frost is passed the heavier the yield. The pea is usually sown broadcast at the rate of 2 bushels per acre and plowed or harrowed in. The cowpea is not affected by heat, and is less sensitive to drought than any of the clovers."

Experiments have shown that cowpeas respond readily to applications of potash and phosphates, and are able to derive their nitrogen very largely from the air. Inasmuch as cowpeas are large gatherers of nitrogen, and also secure considerable amounts of potash and phosphoric acid through their extensive root system, which reaches down to the subsoil, they have a high fertilizing value. How to get the greatest benefit from the fertilizing constituents of cowpeas is one of the problems on which the experiment stations are working. If the cowpeas are plowed under in the fall and the ground left bare until spring a large share of the nitrogen will be leached away. By sowing wheat or rye after the cowpeas are plowed under part of this loss may be avoided. If the vines are cut and allowed to lie on the ground during the winter the nitrogen is rapidly lost. In an experiment at the station in Alabama it was found that vines gathered in October had from 1.45 to 2.62 per cent of nitrogen, while if left on the ground until January they had only about 0.70 per cent, *i. e.*, they lost two thirds of their most valuable fertilizing ingredient.

Experiments at the Louisiana station show that 1 acre of cowpeas, yielding 3,970.38 pounds of organic matter, turned under, gave to the soil 64.95 pounds of nitrogen, 20.39 pounds of phosphoric acid, and 110.56 pounds of potash, of which at least 8.34 pounds of nitrogen, 4.43 pounds of phosphoric acid, and 18.1 pounds of potash were furnished by the roots. Analyses made at the South Carolina Station show that cowpea hay contains 1.42 per cent of potash, 0.39 per cent of phosphoric acid, and 2.71 per cent of nitrogen. Cowpea roots contained 1.19 per cent of potash, 0.28 per cent of phosphoric acid, and 0.94 per cent of nitrogen; the roots and stubble, two months after the crop was harvested, contained 0.83 per cent of potash, 0.26 per cent of phosphoric acid, and 1.35 per cent of nitrogen. Experiments elsewhere showed that the vines from a given area weighed six times as much as the roots, and were 8⅓ times as valuable for manure.

Cowpeas and melilotus have given good results as green manure on the canebrake lands of Alabama. "Before the land was sowed in melilotus and cowpeas it was not considered worth cultivating. This season (1890) it produced as fine a crop as the best lands of the station highly fertilized."

ALFALFA.

Alfalfa or lucern has long been cultivated in Europe, and is grown quite extensively in some of the Western and Southern States. It seems probable that it may be introduced with advantage into many parts of the Southern States east of the Mississippi, and over a wide tract of the more arid regions of the Southwest. Under favorable conditions it will live from eight to fifteen years, and does not run out as clover does. It has been grown successfully for seven years at the experiment station at Geneva, N. Y., but in recent experiments on 30 farms in different parts of Vermont it was very largely winterkilled. While a Southern climate is more favorable to alfalfa, numerous experiments have shown that it will do well in many localities in the Northern States, and when established will produce from three to five crops each season for a number of successive years. Alfalfa is said to be especially adapted to dry climates, and withstands drought much better than ordinary clovers. For this reason it is largely relied on in Colorado and California, especially where irrigation is used.

The value of alfalfa for green manuring has been quite thoroughly studied by the New Jersey Experiment Station. Seed was sown broadcast at the rate of 15 pounds per acre. A fertilizer containing phosphoric acid and potash with a little nitrogen was applied. It appears from these studies that alfalfa derives nitrogen from some other source than the soil, and draws potash through its long roots from the deeper layers of the subsoil. In three years 90 pounds of nitrogen per acre was applied in the fertilizer, and the crops harvested in that time contained 912.8 pounds of nitrogen per acre. The fertilizing materials contained in the crops harvested in four years are shown in the following table:

Fertilizing ingredients in alfalfa during different seasons.

Year.	Pounds per acre.		
	Nitrogen.	Phosphoric acid.	Potash.
1886	261.6	39.6	203.5
1887	253.6	45.7	286.9
1888	299.2	52.4	292.2
1889	360.0	63.0	255.5

The average of the above table is 304 pounds of nitrogen, 50 pounds of phosphoric acid, and 260 pounds of potash a year. These amounts would be furnished by a dressing of 1,900 pounds of nitrate of soda, 500 pounds of muriate of potash, and 300 pounds of South Carolina superphosphate. The phosphoric acid and potash were naturally derived from the soil. The 300 pounds of nitrogen would cost in the form of nitrate of soda, at the present low price of 15½ cents a pound, $46.50.

RED CLOVER.

Red clover has been cultivated for centuries. It succeeds best in a temperate climate not deficient in moisture. In the central and eastern part of the United States it constitutes one of the most important hay crops. Though not generally grown in the Gulf States it succeeds on the strong clay lands and black prairie soil of the South. It may be grown as far north as Minnesota, but frequently does not thrive in newly settled sections. It has been successfully grown all over Nebraska, where it is recommended for early pasture as well as for hay, and where it withstands drought. It has proved valuable in South Dakota. Most of the experiment stations give favorable reports of this plant. In Nevada, however, without water the growth is light.

As a green manure it is perhaps more extensively used in the United States than any other plant. Twenty pounds of seed per acre is the quantity usually recommended. The seed is frequently adulterated with weed seed. At the Mississippi Station light-colored and dark seed germinated alike in the ground. Clover is sown broadcast. In cold climates spring sowing is customary. The Connecticut Storrs Station recommends sowing after grain in the latter part of July, in order to secure an early crop the next season. In the South seeding in September or October and in February is successful. In Kentucky seed sown between February 2 and March 1 nearly all germinated.

Studies of the root system of red clover grown at the Minnesota Station showed that the amount of roots and the depth to which they penetrate vary greatly, depending on the character of the land. In a favorable soil a plant one month old had a root extending 7 inches into the ground; at two months old it had reached a depth of 2 feet; at five months its length was 5 feet 8 inches. The root development is most extensive on drained land. The stand is also better on drained than on undrained soils.

CRIMSON CLOVER.

Crimson clover, also called scarlet clover and Italian or German clover, grows from 1 to 2 feet high, with flower heads from 1½ to 2 inches long and of a bright crimson color. Though not generally grown in the North it made a growth of 26 inches at the Maine Station. It thrives on soil too light for other clovers. In the South it is valuable on non-calcareous, sandy, or light clay soils. It has been highly recommended for green manuring and its value for that purpose has been studied especially by the Delaware Experiment Station. That station reported that in 1891 2,340 acres of crimson clover were grown in Delaware, 1,277 acres being used for green manuring. It is sown both in the open field and in orchards. The quantity of seed used depends upon the aims of the sower, varying between 5 and 15 pounds per acre. It is also sown among corn, and with a broadcasting machine 4 acres per hour can be seeded. It may be grown either as a winter crop, covering the soil during September, October, and November, or as a summer crop. As a winter crop it may either precede or follow the Southern cowpea vine. In Delaware a very large acreage of field corn is sown to crimson clover immediately after the cultivation of the corn is finished for the season.

Crimson clover is sown in Delaware the latter part of July or during August. In the South the seed may be sown from August till the middle of September or even later in extreme southern latitudes. It is important that considerable growth should be made before winter. On the other hand, to obtain a good stand, one must wait for a suitable season. It is not necessary to prepare the land especially for the clover crop, but the seed may be sown in fields of cotton, corn, or vegetables immediately after the cultivation and without covering. If clover is the only crop a light brushing or rolling is in order. The seed may also be sown among the vines of a pea crop. Crimson clover begins its growth as the peas die, and these two renovating crops supply a very large amount of organic matter to the soil.

Failure to secure a stand of crimson clover is frequent, due sometimes to the seed and sometimes to the season. The newly germinated plants are easily killed by a scorching sun. On stubble land a catch may be secured by harrowing deeply and then sowing the seed and rolling or harrowing lightly.

In Delaware crimson clover can be cut for hay or for silage early in May. In the South it blooms in April. A yield of from 1 to 2 tons of excellent hay may be secured from very thin land. The hay is taken off in time to allow the use of the field for other summer crops. In Delaware some farmers, while plowing under the green crop in orchards, turn the furrows so as to leave the heads of clover above ground. These heads bear seed and thus afford a stand the next year. In cutting for hay in orchards other farmers leave strips of uncut clover along the rows of trees. From these strips the seed is scattered for the next year's crop.

Crimson clover may follow grain or grass as well as cultivated crops. After cultivated crops it usually makes a good catch with slight expense. Orchards on thin soils may be benefited by plowing in crimson clover for several years in succession. On rich soil and for some crops it is possible to incorporate too much organic matter with the soil. Crimson clover leaves the land in good condition for a crop of cotton, corn, or vegetables. It has been found an excellent substitute for nitrate of soda in growing sweet potatoes in Delaware.

At the Delaware Experiment Station crimson clover yielded at the rate of 13 tons 566 pounds of green material per acre (exclusive of roots and stubble), containing 131 pounds of potash, 35 pounds of phosphoric acid, and 115 pounds of nitrogen. As a source of nitrogen for fruits, field crops, and vegetables it has given highly satisfactory results, in some cases surpassing nitrate of soda.

The following illustration of the result of using crimson clover for green manuring is from a recent report of the Delaware Experiment Station:

> Seed of crimson clover costing $1 per acre was sown in a corn field near Newark, in 1891, immediately after the last cultivation of the crop. The clover passed out

of blossom during the first week of June, 1892. A test made at that time indicated that the green crop then standing weighed 8 tons 600 pounds per acre. It was plowed under on the 5th instant; Mastodon seed corn was planted on the 7th. An adjoining plat upon which tomatoes had been grown in 1891, and upon which no clover had been seeded for many years, was also planted with the same variety of corn on the 7th instant. A portion of this corn on the tomato plat was top-dressed with nitrate of soda, 100 pounds per acre, costing $1. The tomato plat yielded 24 bushels of shelled corn per acre, the tomato plat with nitrate of soda yielded 30 bushels, and the plat manured with crimson clover yielded 48 bushels.

Eight tons 600 pounds of crimson clover from seed which cost $1 per acre added 24 bushels to the corn crop. One dollar invested in nitrate of soda and used as a top-dressing added 6 bushels to the corn crop. Hence in this case $1 invested in clover seed returned four times as much as $1 invested in nitrate of soda. As to the relative amount of labor involved the sowing of the seed and the broadcasting of the nitrate possibly balance each other. Plowing down a green crop is doubtless far more costly than plowing bare ground. This drawback may reduce the above-named apparent gain by approximately 25 per cent.

JAPAN CLOVER.

Japan clover (*Lespedeza striata*) has been very successfully grown at the North Carolina Experiment Station and is strongly recommended as a renovator of worn soils. At the station it was grown on a very poor stiff clay soil with a light dressing of phosphate. Other clovers, lucern, and serradella, did very poorly on this soil, but the Japan clover presented a most luxuriant appearance throughout the season. The seed is broadcasted at the rate of about 12 pounds per acre and covered with a smoothing harrow or roller. The seed costs from 12 to 20 cents a pound, and can be bought of most of the larger seed firms. The seed should be sown in the spring after danger of frost is over, as the plant is very tender. Japan clover seems to prefer a moist clay soil, but does well on almost any soil except pure sand, and thrives without fertilizer on exhausted soils. Drought checks its growth for a time, but not seriously.

The North Carolina Station says:

> The ability to grow on land too poor to produce even broom sedge, and to crowd out all other plants; its dying each winter and leaving its roots to fertilize the soil; and its possessing the nitrogen-fixing power peculiar to the pulse family of plants, place Japan clover at the head of renovating plants adapted to the climate of Southern States. It is unequaled as a restorer of worn fields, such as are generally turned out to grow up in pines.

LUPINES.

The three species of lupines more commonly grown are the white, the yellow, and the blue lupine. The plants are bushy, somewhat woody, and generally too coarse for good fodder, though they are used in some countries for sheep. The seed is exceedingly nitrogenous and in Europe is used for cattle food. As it contains a bitter alkaloid injurious to animals it must be disembittered before feeding. Kellner's process of disembittering lupine seed consists in soaking the seed in water for twenty-four hours, with frequent changes of water, steaming for one hour, and then extracting for two days, with frequent stirring. In the latter operation the discolored water is drawn off frequently and fresh water added. Five pounds daily of this disembittered lupine seed may be fed to cows per 1,000 pounds live weight.

Lupines are much used in Europe for green manuring. They thrive on a light sandy soil, make a rapid growth, and produce large amounts of organic materials, which when plowed into the soil improve it in humus and enrich it in nitrogen. A practice recommended for bringing up very poor soils is to grow a crop of lupine manured with kainit, turn the crop under, and follow it with winter rye manured with Thomas slag phosphate.

In order to derive the greatest possible advantage from the green manuring, the lupines should be sown early in May. By the first half of August, which is believed to be the best time of the year for plowing under, the seed of the lupine will be nearly or quite formed, and the crop will contain the maximum quantity of nitrogenous matter. Four, or better six, weeks should intervene between the plowing under of the lupine and the sowing of the rye.

Under such a rotation a poor sandy soil will gradually improve in humus until the change is perceptible to the eye in the darker color of the soil, and there will likewise be an increase in fertility.

In Europe large tracts of barren waste have been brought into condition for profitable cultivation by green manuring with lupines treated with phosphates and potash salts.

COMPOSITION OF GREEN LEGUMINOUS CROPS.

The following table gives the average amounts of water and fertilizing materials in 100 pounds in a number of green leguminous crops:

Fertilizing ingredients in 100 pounds of green leguminous crops.

	Moisture.	Nitrogen.	Phosphoric acid.	Potassium oxide.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Red clover	80.00	0.53	0.13	0.46
White clover	81.00	0.56	0.20	0.24
Alsike clover	81.80	0.44	0.11	0.20
Crimson clover	82.50	0.43	0.13	0.49
Alfalfa	75.30	0.72	0.13	0.56
Cowpea	78.81	0.27	0.10	0.31
Serradella	82.59	0.41	0.14	0.42
Soja bean	73.20	0.29	0.15	0.53
Horse bean	74.71	0.68	0.33	1.37
White lupine	85.35	0.44	0.35	1.73
Yellow lupine	83.15	0.51	0.11	0.15
Flat pea (*Lathyrus sylvestris*)	71.60	1.13	0.18	0.58
Common vetch	84.50	0.59	1.19	0.70

GREEN MANURING COMPARED WITH FEEDING THE CROP.

In spite of the many advantages of green manuring, there are conditions under which it can not be regarded as a rational and profitable practice. It involves the absolute waste of large quantities of the very best kind of fodder. For this reason green manuring on good soils can only be recommended when the conditions of farming do not admit of the careful preservation of manure. The crops should be fed to animals and the manure carefully saved and returned to the soil. It is in this manner only that the full value of the crop can be secured. By feeding the crop this animal food is saved, and at the same time from three quarters to nine tenths of the fertilizing materials (nitrogen, phosphoric acid, and potash) in the crop may be returned to the soil in the manure, if this is properly cared for. Animals need for their nutrition nitrogen, fat, and carbohydrates (starch, sugar, etc.). The nitrogen in foods is in the form of protein (albuminoid materials). It is the same nitrogen which in green manuring enriches the soil. These leguminous crops are unusually rich in protein—far richer than most other coarse fodders. For instance, while hay from grasses contains from 6 to 8 per cent of protein, red clover hay contains 12.5 per cent, alfalfa hay 14.3 per cent, and cowpea hay 16.6 per cent of protein. If grass hay and corn are fed, such concentrated feeding stuffs as cotton-seed meal, gluten meal, linseed meal, etc., must be fed to make up the supply of protein needed. If leguminous crops are fed, much less grain will be required.

As nitrogen is the most expensive fertilizing element, so protein (nitrogen) is also by far the most expensive food element. By feeding the leguminous crops instead of plowing them under a twofold result is secured—animals are nourished without buying expensive grain feeds, and the soil is enriched to very nearly the same extent as in green manuring.

Beyond question the nitrogen of the air, which is obtained without cost through the agency of leguminous plants, is best utilized in improving the productiveness of the land and increasing the profits of the farm when it is used in the production of milk and meat and thereby in the production of cheap barnyard manure. What has been said of the nitrogen applies also to the carbohydrates and fats which the plant derives from the carbonic acid of the air. If the crop is fed, the carbohydrates and fat serve to nourish the animal and a portion in turn passes into the barnyard manure, and when applied to the soil has a favorable effect on the humus formation. This is the true economy of material. It is following out the law of nature. Its profitableness will depend upon the price of feeding stuffs in general. The higher the prevailing price of hay and other feeding stuffs the larger will be the profit from feeding the crop rather than using it for green manuring. Let us consider a few examples of the value of a crop for green manuring and for feeding on different kinds of soils.

SERRADELLA ON MEDIUM SANDY SOILS.

Take, for instance, the case of serradella on the better class of sandy soils. This plant does well on medium light sandy soils. It may be sown among winter rye in spring. Under these conditions it produces an unusually luxuriant vegetation which may either be plowed under with good effect on the crop following, or it may be pastured. Serradella is an excellent fodder plant and may be fed with none of the danger attending the feeding of lupines. It may be fed either green or as hay or silage. It is eagerly eaten by all kinds of farm animals, retains its palatability and food value up to the end of blooming, and has a very favorable effect on the secretion of milk.

The claim is frequently made, in advocating growing serradella for green manuring, that it is an exceedingly cheap means of securing nitrogen; that with a small expenditure for seed, and no extra labor except that of sowing the seed, a large amount of nitrogen is secured from the air. Admitting this, has not this nitrogen, in the form in which it exists, namely, as protein, a much higher value when used for feeding animals than when plowed under? If it is a cheap source of nitrogen for manuring, is it not also a cheap source of protein for feeding, especially when three quarters of the nitrogen in the crop is recovered in the manure?

A German authority on feeding and farm management has calculated the matter on a financial basis. Assuming an average crop of 17,600 pounds of green serradella, which is a moderate crop, he finds the nitrogen in the crop from an acre to be worth $11.06. This is taken as the value of the crop for green manuring, as the nitrogen is the only fertilizing element not derived from the soil, and the barnyard manure furnishes nearly as much humus as green manuring.

The estimated profit from feeding the crop of 17,600 pounds of green serradella to milch cows, when the barnyard manure is returned to the soil, is $23.12. In this calculation every possible expense attending the feeding is taken into account, including care of animals, interest on money, cost of carting the barnyard manure to the land, etc., and allowance is made for the phosphoric acid and potash sold in the milk. The comparison stands then as follows:

Profit from feeding crop of serradella from 1 acre	$23.12
Value of crop of serradella from 1 acre for green manuring	11.06
Difference	$12.06

This calculation shows the crop of serradella to be more than twice as valuable for feeding as for green manuring.

The above calculation assumed a daily milk yield of 7½ quarts, sold at 2¼ cents per quart. On the basis of only 1½ cents per quart of milk, the feeding value would be $13.52, or still $2.46 higher than the value for green manuring.

GREEN MANURING ON MEDIUM RICH SOILS.

Green manuring on medium rich soils has much less to recommend it than on sandy soils. Although the green manuring of light sandy soils with lupines is often of very great advantage in enriching the soil in humus, this advantage does not hold good in the case of better soils.

There are other plants better adapted than lupines to serve as fallow crops on these better soils. Serradella does well, but as a rule is not to be recommended for a principal crop, and when sown with rye, giving a good yield, it is often so choked out as to amount to very little. But where it can be grown with advantage as a first crop on better soils it must be fed to be utilized to the fullest extent, as pointed out above.

Peas and vetch are especially adapted for fallow crops, and can be recommended for green manuring. But as they are also good fodder plants, all that has been said above regarding this subject applies to them with equal force.

An experiment of interest in this connection was made at the Agricultural Institute at Halle, Germany, in 1891. About 3 acres of land was used which had been in winter wheat in 1890 and in winter rye in 1891. A mixture of 194 pounds of white field peas, 44 pounds of common sand vetch, and 35 pounds of yellow lupine seed per acre was sown August 11. The crop was plowed under October 28. A good growth had been made and the crop was fitted either for green manuring or for feeding. The yield was at the rate of 8,650 pounds of green material per acre. This contained by analysis 0.575 per cent of nitrogen, or 49.74 pounds of nitrogen per acre, which at 15 cents per pound gave a value for the crop for green manuring of $7.46 an acre.

In the spring of 1892 white pearl barley was sown on the whole area and also on an adjoining piece not green manured. The crops were harvested August 18, with the following results per acre:

Yield of barley per acre with and without green manuring.

	Grain.	Chaff.	Straw.
	Bushels.	*Pounds.*	*Pounds.*
Plat green manured with peas, vetch, and lupine	61.38	366	3,260
Plat not green manured	61.48	385	2,908

An effect of the green manuring is only noticeable in the amount of straw, which is larger by about 350 pounds per acre where the mixture of peas, vetch, and lupine had been plowed in.

The barley crop from the green-manured plat contained 68.56 pounds of nitrogen per acre, and that from the plat not green manured 56.6 pounds of nitrogen. This difference of 11.96 pounds of nitrogen is nearly all accounted for by the nitrogen contained in the seed sown on the green-manured plat, so that it may be that on this medium rich soil green manuring was without any effect whatever on the crop immediately following it. The pea and vetch plants produced root tubercles, and it is probable that had the plants been allowed to fully develop and ripen the effect of the tubercles would have been much more apparent in the amount of nitrogen in the crop plowed under. But the richer the soil is the larger the proportion of nitrogen which will be taken from the soil and the less from the air. This nitrogen-gathering appears to go on best in a soil deficient in available nitrogen, as already mentioned.

The author estimates the green forage as worth $3 per ton for feeding, which would make the crop worth $13 per acre, or $5.54 more per acre than the estimated value for green manuring.

GREEN MANURING ON SANDY LOAM SOILS.

Compared with the above green-manuring trial on medium rich soil, the result was quite different in a similar trial in 1891 on a sandy loam soil poor in humus. A piece of land which for many years had received uniform cropping and manuring was divided into two plats of about one fourth acre each. Rye had been grown on both plats that season. On one plat white field peas were sown in the rye stubble August 15. The other plat was given the same preparatory treatment, but remained bare. Both plats were plowed November 2. The pea vines had grown to a height of 15 to 18 inches, and a large weighed sample showed that the green crop was at the rate of 3½ tons per acre, containing 37⅓ pounds of nitrogen.

March 23, 1892, barley was sown on both plats. The green-manured plat received no other manuring, but the other plat received an amount of nitrate of soda furnishing 28 pounds of nitrogen per acre. The barley was harvested August 9. The yield on the two plats was practically the same. The agreement in percentage of nitrogen is equally striking. The total nitrogen per acre in the crop from the green-manured plat was 60.34 pounds, and from the nitrate of soda plat 60.12 pounds. The green manuring, with 37.33 pounds of nitrogen per acre, had given a result equally as good in every way as an application of 28 pounds of nitrogen per acre in the form of nitrate of soda. But even with this favorable result there was no financial advantage from the green manuring as shown by this single crop. It furnished 37.33 pounds of nitrogen per acre, which at 15 cents per pound would be worth only $5.60, which would no more than pay for the pea seed used.

ALFALFA AND CRIMSON CLOVER FOR FEEDING.

Suppose that, instead of being plowed under, the alfalfa grown at the New Jersey Experiment Station, as referred to (p. 9), had been fed to animals and the manure carefully saved and returned to the soil. The total yield of four cuttings during the season of 1889 was about 23 tons of green alfalfa per acre. The value of this crop for fodder at $3 per ton would be $69 as compared with its value of $46.50 for green manuring, and it is fair to assume that some $35 worth of nitrogen would be returned to the soil in the manure. The crop of 13¼ tons of crimson clover reported elsewhere (p. 11) would be worth about $40 for feeding as compared with $17.25 for green manuring. When made into hay crimson clover is an excellent feeding stuff and rivals bran in composition. Instead of cutting the crop it may be pastured to advantage.

COWPEA FOR FEEDING.

A prominent agriculturist in the South says of the cowpea:

> For the production of a nitrogenous food in the shape of a forage crop the cowpea vines are almost without a rival. * * * On an acre of ordinary land this crop will probably produce more digestible food than either oats or corn. The manure resulting from feeding this crop is of the highest value and should be carefully preserved and returned to the land.

At the Rhode Island Experiment Station a crop of 17½ tons of green cowpea forage was harvested. This contained 157½ pounds of nitrogen, which at 15 cents per pound would make the crop worth $23.63 per acre for green manuring. At $3 per ton the 17½ tons would be worth $52.50 for feeding and there would be less than one third of the fertilizing ingredients lost in feeding the crop.

What has been said of the above crops applies with equal force to other crops commonly used for green manuring. The matter resolves itself into this, that on medium and better classes of soils green manuring is not as profitable as feeding the crop. When the crop is fed the stubble and roots are left to the soil, and they together with the manure enrich the soil in fertilizing materials and in humus to very nearly the same extent as plowing the whole crop under. With the exception of perhaps one fourth of the fertilizing materials, the soil shares all the advantages to be obtained from green manuring when the crop is fed and the manure preserved. More labor is involved in feeding but in return more milk and more beef are made, or the purchase of expensive grain is largely avoided.

In a rational system of farming not a single pound of protein which can be used as food for stock should be plowed into the soil. Of course there are conditions under which green manuring is to be recommended in preference to feeding the crop, and unfortunately such conditions prevail at present over a considerable part of this country. Unless the manure is carefully collected and preserved the advantages from feeding disppear to a large extent. In some sections of the country, even where manures are at present necessary, little or no care is taken of the barnyard manure. A large proportion of the fertilizing and humus-forming ingredients is lost, either through leaching, surface-washing, or fermentation and decay. The farmer who permits this waste, whether through ignorance or carelessness, is sure to feel the loss either in diminished crops or in increased bills for fertilizers. The barnyard manure should be as scrupulously cared for as any other farm product. It has been repeatedly shown in experiments in the East in growing stock for beef, mutton, and pork that a very large proportion of the profit was in the manure. If the value of the manure was left out of the account there was little or no profit from the operation. If the manure was valued at current rates for fertilizing materials a fair profit was apparent

ADVANTAGES OF SOILING.

The advantages of soiling, or feeding animals largely or wholly on green forage crops in the barn instead of pasturing them, are that less land is required to maintain a given number of animals, the food supply can be better regulated, the animals do not waste their energy in searching for food, and the manure can all be saved and applied to the soil. The arguments for partial soiling are that the amount of feed furnished by pastures is very irregular, being usually abundant and of good quality early in the season, but falling off later from droughts or early frosts. In the case of milch cows unless some supplementary food is given at such times the milk flow diminishes and the cows fall off in flesh.

Concerning the relative amounts of food furnished by pasturing and by soiling, the Pennsylvania Experiment Station found in experiments in two years that "in round numbers we can produce from three to five times as much digestible food per acre by means of the soiling crops (rye and corn or clover and corn) as is produced by pasturage such as is represented by our small plat." The plat in question was believed to fairly represent the average pasture. From feeding trials with the above soiling crops and pasture grass the average yield of milk per acre was calculated as follows:

Yield of milk per acre of land.

	1888.	1889.
	Pounds.	*Pounds.*
Soiling	3,416	5,671
Pasturage	928	1,504
Difference	2,488	4,167

It will be understood that the above is partly an estimate, but it points very strongly in favor of soiling.

Trials at the station in Wisconsin showed that "by soiling in summer a certain area of land will yield double the amount of milk and butter that it will when pastured."

The Connecticut Storrs Experiment Station maintained 4 cows from June 1 to November 1 on a little less than 2½ acres of soiling crops with the addition of a very light grain and straw feed.

At the Ontario Agricultural College and Experimental Farm about three fourths of an acre of soiling crops (green clover, green peas, tares, oats, and corn fodder) was sufficient, with the addition of 252 pounds of wheat bran, for 2 cows for sixty-three days. "We might expect, therefore, to grow on about 1 acre sufficient green food to feed a cow for two hundred days under ordinary conditions."

If soiling is to be practiced it is important to have a succession of green fodders throughout the growing season, with each in its best stage of growth for feeding. There should be no breaks in the succession and each crop should be used as nearly as possible at the time when it contains the largest amount of valuable food constituents.

From three years of experience and observation in the practice of soiling, the Connecticut Storrs Station suggests the following series of crops for soiling in central Connecticut:

Crops for soiling in central Connecticut.

Kind of fodder.	Amount of seed per acre.	Approximate time of seeding.	Approximate time of feeding.
1. Rye fodder .... bushels..	2½ to 3 ..	Sept. 1	May 10–20.
2. Wheat fodder .... do....	2½ to 3 ..	Sept. 5–10	May 20–June 5.
3. Clover .... pounds..	20.......	July 20–30	June 5–15.
4. Grass (from grass lands)	....	....	June 15–25.
5. Oats and peas (each) .... bushels..	2.......	Apr. 10	June 25–July 10.
6. Oats and peas (each) .... do....	2.......	Apr. 20	July 10–20.
7. Oats and peas (each) .... do....	2.......	Apr. 30	July 20–Aug. 1.
8. Hungarian grass .... do....	1½.......	June 1	Aug. 1–10.
9. Clover rowen (from 3)	....	....	Aug. 10–20.
10. Soja beans .... bushels..	1.......	May 25	Aug. 29–Sept 5.
11. Cowpeas .... do....	1.......	June 5–10	Sept. 5–20.
12. Rowen grass (from grass lands)	....	....	Sept. 20–30.
13. Barley and peas (each) .... bushels..	2.......	Aug. 5–10	Oct. 1–30.

The growing of a leguminous plant and a cereal together, as oats and peas, to be fed as green forage, has proved quite popular where it has been tried. The experiment stations in nearly every State have tested the adaptability of various fodder plants, leguminous and nonleguminous, and can furnish information as to selection, where seed can be obtained, etc.

By a judicious selection of soiling crops not only can a much larger number of cows be kept on a given area of land, but the land may be brought into a higher state of cultivation and fertility, and much grain may be spared.

Soiling is a feature of a more intensive system of farming, and finds more extensive application as the value of the land increases.

VALUE OF LEGUMINOUS CROPS FOR FEEDING.

Why should the farmer go on raising meadow hay as his main supply of coarse fodder and buying grain to supplement it, when by growing leguminous crops the nitrogen required by animals can be produced at the lowest cost? The crops of red clover, crimson clover, Japan clover (*Lespedeza*), cowpea, alfalfa, soja bean, horse bean, serradella, and many others of this class far surpass common hay in the food materials they contain, both pound for pound and in yield per acre. They may be grown as catch crops and used for soiling or pasturage, or they may be grown for making hay or silage. By mixing the green crops with corn and ensiling the two together a palatable and nutritious food is produced which is much richer in protein (nitrogen) than silage made from corn alone.

The cultivation of these leguminous plants involves somewhat more labor, as a rule, than raising grass hay, but it is believed that it will prove profitable for it enables the farmer to raise his own concentrated feed at the same time that he raises his coarse fodder. For instance, a recent experiment has indicated that soja-bean meal is fully equal to cotton-seed meal for milk and butter production. This meal is one of the richest feeding stuffs we have. It exceeds linseed meal and gluten meal in protein (nitrogen) and far exceeds these and cotton-seed meal in fat. It is only surpassed in protein by cotton-seed meal and some of the oil cakes little used in this country. The beans can be thrashed out and ground and the straw fed as coarse fodder. This straw is richer in food materials than a good meadow hay. It contains 9½ per cent of protein while meadow hay averages about 7½ per cent. The cowpea may be treated in similar manner. The ground cowpeas are a richly nitrogenous feed, although not as rich as soja-bean meal; and the vines are nearly or quite equal to clover hay and far surpass grass hay in richness.

The following table shows the average composition of hay from leguminous crops as compared with hay from grasses:

Average composition of hay from grasses and leguminous crops.

Hay from—	Water.	Protein.	Carbohydrates.	Fat.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Red top	8.9	7.9	76.0	1.9
Orchard grass	9.9	8.1	73.4	2.6
Timothy	13.2	5.9	74.0	2.5
Hungarian grass	7.7	7.5	76.7	2.1
Kentucky blue grass	15.0	8.2	78.1	4.4
Red clover	15.3	12.3	62.9	3.3
Crimson clover	13.4	14.0	55.6	4.1
Japan clover	10.9	13.8	63.1	3.7
Alsike clover	9.7	12.8	66.3	2.9
White clover	9.7	15.7	63.4	2.9
Alfalfa	8.4	14.3	67.7	2.2
Cowpea	10.7	16.6	62.3	2.9
Serradella	9.2	15.2	65.7	2.6
Vetch	8.4	14.5	67.8	2.1
Soja bean	6.3	14.5	66.6	5.6
Average for grasses	10.94	7.52	75.64	2.70
Average for leguminous plants	10.20	14.37	64.14	3.23

It may be said in general that 100 pounds of hay from leguminous crops contains about twice as much protein as 100 pounds of hay from grasses. The leguminous hay may be safely estimated as worth from one fourth to one third more for feeding than common hay. This is true in spite of the fact that it does not usually command a higher price in the markets, owing to certain prejudices against its use.

Assuming that the common grasses yield 2 tons of hay to the acre, and clovers, etc., 3 tons of hay, the amounts of food materials and fertilizing materials in the crops are approximately as follows:

Relative yield of food and fertilizing materials in crops of hay from grasses and from leguminous crops.

Hay from—	Assumed yield per acre.	Food materials in crop per acre.			Fertilizing materials in crop per acre.		
		Protein.	Carbohydrates.	Fat.	Nitrogen.	Phosphoric acid.	Potash.
	Tons.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Red top	2	158	1,520	38	23.0	7.2	20.4
Timothy	2	118	1,480	50	25.2	10.6	18.0
Red clover	3	369	1,887	99	62.1	11.4	66.0
Alfalfa	3	429	2,031	66	65.7	15.3	50.4
Cowpea	3	498	1,869	87	58.5	15.6	44.1
Soja bean	3	435	1,998	168	69.6	20.1	32.4

The amount of hay produced on different farms varies so widely that it is difficult to strike an average, especially for the leguminous crops. It will be seen that on the above basis, which is believed to be a fair one, the leguminous crops furnish from two to four times as much protein per acre as common grasses, together with much more fat and rather more carbohydrates. They also contain nearly three times as much nitrogen and about twice as much potash. It should be remembered that under favorable conditions they may draw a large proportion of this nitrogen from the air, instead of depleting the soil, and that their long roots enable them to feed upon the potash deep down in the soil beyond the reach of surface-feeding plants.

SUMMARY.

(1) Green manuring improves the physical properties of the soil by making the soil more porous and adding to its supply of humus. It brings up the dormant plant food from deep down in the soil and deposits it near the surface, where it can be used by plants feeding near the surface.

(2) Green manuring with buckwheat, Hungarian grass, and other non-leguminous plants adds practically nothing to the soil which was not there before, except a mass of vegetable matter which decays and goes to form humus.

(3) Green manuring with clovers, peas, beans, lupines, etc. (leguminous crops), actually enriches the soil in nitrogen drawn from the air. These plants can grow with very little soil nitrogen. They store up the nitrogen of the air as they grow, and when plowed under give it up to the soil and to future crops. It is the cheapest means of manuring the soil with nitrogen.

(4) But animals, as well as plants, require nitrogen for food. By feeding the crops of clover, cowpea, etc., only about one fourth of the fertilizing materials of the crop is lost if the manure is properly cared for. As the nitrogen of the air is the cheapest source of nitrogen for

plants, so it is the cheapest source of protein (nitrogen) for animals. The leguminous crop is best utilized when it is fed out on the farm and the manure saved and applied to the soil. The greatest profit is thus secured and nearly the same fertility is maintained as in green manuring.

(5) For renovating worn or barren soils, and for maintaining the fertility where the barnyard manure is not properly cared for, green manuring with such leguminous crops as cowpea, clovers, and lupines is recommended. A dressing of potash and phosphates will usually be sufficient for the green manuring crop.

(6) The practice of green manuring on medium and better classes of soils is irrational and wasteful. The farmer should mend his system so that the barnyard manure will be as well cared for as any other farm product. Loss from surface washing, leaching, fermentation, and decay should be guarded against. Then the feeding of richer food will mean richer manure and better and cheaper crops.

(7) The system of soiling, or feeding green crops in the barn in place of pasturage, enables a larger number of animals to be kept on a given area of land, and the manure to be more completely saved. For this purpose leguminous crops are extremely valuable.

(8) Hay from leguminous crops is about twice as rich in protein as hay from grasses. In the one case this protein (nitrogen) is obtained very largely from the atmosphere; in the other it is all drawn from the fertility of the soil. Leguminous crops yield larger crops of hay to the acre than grasses. Hence the production of food materials on an acre, especially protein, is several times larger with leguminous crops.

(9) If allowed to ripen, the seed of the cowpea and soja bean furnishes an extremely rich concentrated feed which can be ground and fed in place of expensive commercial feeds. The straw remaining may be fed as coarse fodder, for it is richer than ordinary hay.

(10) Grow more leguminous crops. They furnish the cheapest food for stock and the cheapest manure for the soil. They do this because they obtain from the air a substance necessary for plants and animals alike, which costs in the form of fertilizers and feeding stuffs from 15 to 25 cents a pound.

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U. S. DEPARTMENT OF AGRICULTURE.

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PEACH YELLOWS AND PEACH ROSETTE.

AGRICULTURAL EXPERIMENT STATION
FEB 11 1898
UNIVERSITY OF ILLINOIS.

BY

ERWIN F. SMITH,
SPECIAL AGENT,
UNDER THE DIRECTION OF B. T. GALLOWAY, CHIEF OF THE
DIVISION OF VEGETABLE PATHOLOGY.

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Farmers' Bulletin No. 16. Leguminous Plants for Green Manuring and for Feeding. By E. W. Allen, Ph. D., Assistant Director of the Office of Experiment Stations. Pp. 23. Issued April, 1894.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Vegetable Pathology,
Washington, D. C., May 11, 1894.

Sir: I have the honor to transmit herewith Farmers' Bulletin No. 17, on peach yellows and peach rosette, prepared under my direction by Erwin F. Smith, special agent of this Division. While the bulletin contains no new facts of importance, it brings together in convenient form the more important information on these subjects. This, in my judgment, is desirable, first, because the diseases are attracting widespread interest, and, second, for the reason that the bulletins heretofore published by the Division on these diseases have been more or less special in their nature and have been issued in such small editions as to be available to but comparatively few fruit growers.

Respectfully,

B. T. Galloway,
Chief of Division.

Hon. J. Sterling Morton,
Secretary of Agriculture.

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PEACH YELLOWS AND PEACH ROSETTE.

PEACH YELLOWS.

Yellows is a disease peculiar to peaches and some closely allied fruits. It has been known for a long time in nectarines, almonds, and apricots, and has been observed recently in Japanese plums, but to what extent the latter are susceptible is not yet known. Other varieties of plums and other stone fruits appear to be exempt. The peach is the only susceptible fruit cultivated on a large scale in the region now subject to yellows, and for this reason what is said in the following pages will relate exclusively to this fruit.

DISTRIBUTION.

Peach yellows is widely distributed in the eastern United States, as may be seen on the accompanying map, and there is no doubt that the extent of infected territory is increasing every year, although rather slowly.

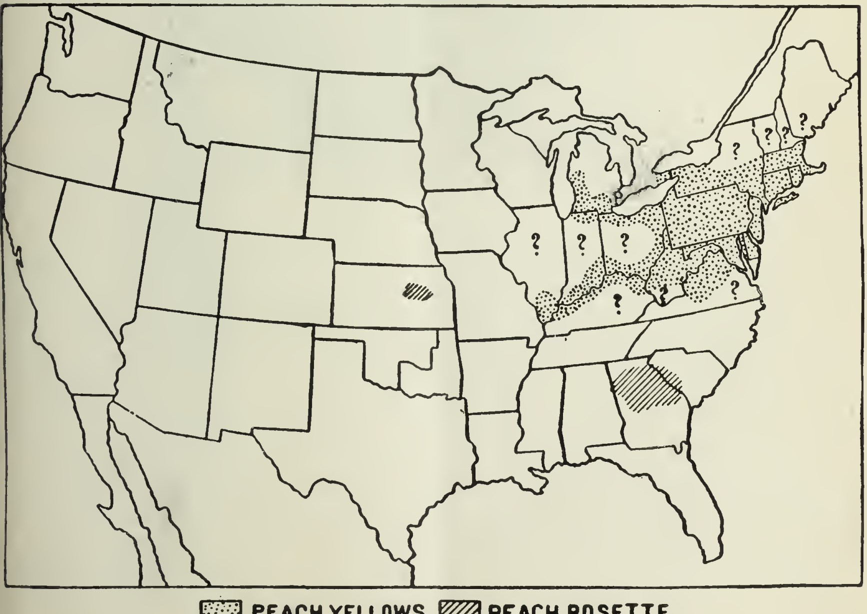

Fig. 1.—Approximate distribution of yellows and rosette. The interrogations denote that the exact limits of the disease are unknown.

The disease is more prevalent in some parts of the designated area than in others, but the localities most severely affected are the very ones most favorable to the growth of the peach and most extensively planted to commercial orchards. In recent years sporadic cases have been reported from several places outside of the limits assigned on the map, e. g., middle Georgia, southeastern Iowa, western Arkansas, and northern Texas. No specimens showing the disease have been received from these States, but statements from western Arkansas are quite explicit and leave little room for doubt that the disease occurs to a considerable extent in that locality. In the last decade this disease has been very destructive in Connecticut, New Jersey, New York, Pennsylvania, Delaware, Maryland, Virginia, Indiana, Illinois, Ohio, and Michigan, in places where formerly it was not regarded as serious.

In this connection it is interesting to note that generally ten or fifteen years suffice for the destruction of the orchards after the disease is once well established, but that sometimes quite a long period intervenes between the discovery of the first scattered cases and that general appearance of the disease in most or all of the orchards of a region which is here meant by the expression "well established." The general movement of the disease on the Delaware and Chesapeake Peninsula and on the mainland of Virginia has been southward; in Michigan it has been north and east; and in New York, northwest.

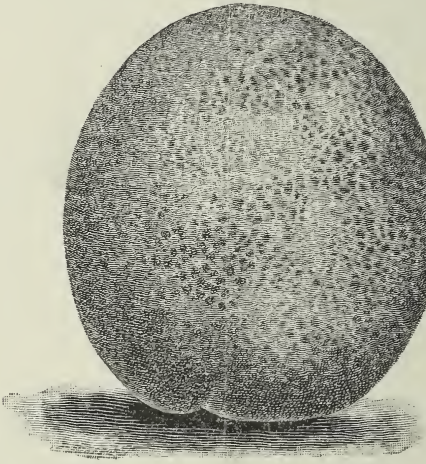

Fig. 2.—A premature peach.

In a number of localities the first cases have certainly appeared in young orchards obtained from infected districts, and there is reason to believe that in all isolated peach regions the first cases will occur in young trees that have been received from places already subject to the disease. Finally, so far as known, this disease has never entirely disappeared from any locality where it has once become well established.

DISTINGUISHING CHARACTERS.

Prematurely ripe, red-spotted fruits, and premature unfolding of the leaf buds into slender, pale shoots, or into branched, broom-like growths, are the most characteristic symptoms of yellows. The time of ripening of premature fruits varies within wide limits; sometimes it precedes the normal ripening by only a few days and at other times by several weeks. The red spots occur in the flesh as well as on the skin, making the peach more highly colored than is natural. The taste of the fruit is generally inferior and often insipid, mawkish, or bitter. Often this premature ripening is the first symptom of yellows. The peaches are then of good size and quite showy, and occur on trees in full vigor, upon limbs bearing abundant green foliage and sometimes also other fruits which afterwards ripen normally.

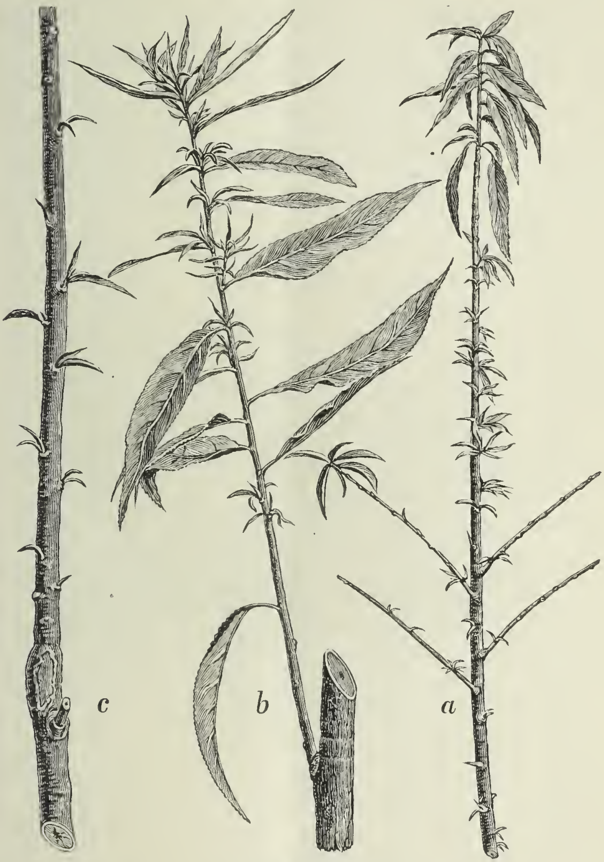

FIG. 3.—Winter buds unfolding in autumn.

Often during the first year of the disease this kind of fruit is restricted to particular limbs or even to single twigs, which, however, do not differ in appearance from other limbs of the tree. The following year a larger part of the tree becomes affected and finally the whole of it, the parts first attacked now showing additional symptoms, if they have not already done so. These symptoms are the development of the winter buds out of their proper season. Like the prematuring of the fruit, the date of this also varies within wide limits. The buds may push into shoots only a few days in advance of the proper time in the spring, or may begin to grow in early summer soon after they are formed and while the leaves on the parent stem are still bright green. This is a very common and characteristic symptom and is especially noticeable in autumn when the normal foliage has fallen (fig. 3 *a*). Usually under the influence of this disease feeble shoots also appear in considerable numbers on the trunk and main limbs. These arise from old resting buds, which are buried deep in the bark and wood and remain dormant in healthy trees. Such shoots are sometimes unbranched and nearly colorless, but the majority are green and repeatedly branched, making a sort of broom-like, erect, pale-green, slender growth, filling the interior of the tree (fig. 4).

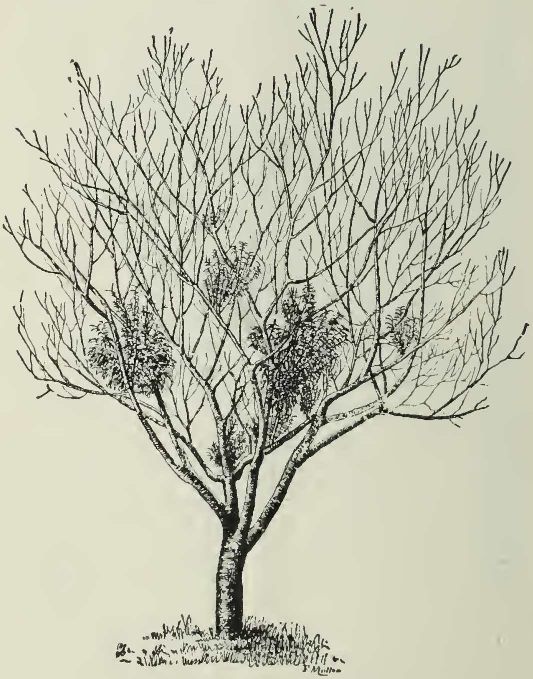

Fig. 4.—Yellows the fourth year.

Such is the general course of the disease, but there is no invariable rule as to its development, the unnatural shoots frequently appearing early in its progress and often attracting more attention than the premature fruit, especially if abundant or associated with a yellowing of the foliage. Following these first symptoms, which generally occur in green and vigorous trees, there is in successive seasons a gradual stunting of the tree and yellowing or reddening of the foliage. This discoloration of the leaves is noticeable at a distance and is undoubtedly responsible for the common name. During these years the original symptoms continue, the tree becoming more and more feeble until it finally dies, the parts first affected dying first. The progress of the disease is slow, an affected tree usually living from three to five years. The usual appearance of such a tree the fourth year is shown in fig. 4, the only living branches being a few broom-like growths arising from the main limbs.

HOW SPREAD.

When the disease appears in young trees, and particularly in a region previously free from yellows, there is good reason for suspecting the nursery, it having been established by repeated experiments that the disease may remain dormant for some time in buds cut from affected trees and afterwards appear in the trees grown from such buds. Fig. 3*b* is an illustration of this. The bud from which this shoot originated was cut in July from a very robust, thrifty watershoot on a healthy-looking branch of an affected tree. Nothing could exceed the vigor and beauty of this watershoot, and yet its buds contained the virus of the disease, which late the same season induced many of the winter buds of the daughter shoots to grow as here shown, although the original buds were set into healthy and vigorous seedlings, which had tops of their own. Of course all of these buds would have remained dormant until the following spring if the shoot had been derived from a healthy bud. Just how long the disease may remain in nursery trees without showing symptoms is unknown. In badly affected regions, where the likelihood of getting diseased buds is greatest, it is not uncommon to find affected trees in the nursery rows the following season, and experience and experiment leave no room for doubt that others showing no symptoms will develop them afterwards when set in orchards. The disease is also readily transmissible to healthy stocks, and can be made to finally destroy all parts of a healthy tree by the insertion of a diseased bud. The disease first appears in that part of the stock next to the inserted bud and subsequently in remoter parts. How soon the stock becomes affected depends in great measure on the character of the inserted bud. If this be taken from a plainly diseased shoot the symptoms appear in the stock sooner than if the bud is taken from such a vigorous shoot as that mentioned above. In either case the progress of the disease is slow. So far as yet known this transmission of the disease from bud to stock can take place only when there is a union of tissues, mere contact, even when close and prolonged, not transmitting the disease. Fig. 3*c* shows a stock shoot (seedling) to which the disease was transmitted by an inserted bud. Under favorable conditions such a seedling lived nearly five years after the insertion of the diseased bud, but never made much growth.

That yellows is also transmitted in some other way must be apparent to any one who has studied the disease at all carefully. In badly affected districts the disease makes a clean sweep and it is impossible to believe that all or even a majority of these trees brought the disease with them from the nursery. The well-established fact that trees with the soundest constitutions readily take the disease, proves that in such cases the cause of the disease must exist in the locality. Now if the disease is not induced in such trees by unfavorable local conditions of soil and climate, both of which explanations seem to have been ruled out by observation and experiment, then the only reasonable supposition is that they contract the disease from neighboring trees already subject to it. This inference rests on the fact that diseased trees are known to be full of a virus readily communicated to other trees by budding, and upon a great number of observations on the behavior of the disease in many badly affected localities.

By some the transmission of the disease has been attributed to the pruning knife, by others to diseased pollen. All that is definitely known is that the disease is communicable by bud inoculation; that trees with the soundest constitutions are subject to it; and that it behaves like an infectious disease, its first scattered appearance in a locality being followed after a longer or shorter interval by the occurrence of cases in many orchards, and this stage by the rapid destruction of the orchards.

There has been much speculation respecting the nature of this disease, inasmuch as climate and soil do not seem able to originate a plainly communicable malady, and no fungi, bacteria, or animal parasites have been identified as the cause. No fungus has been found associated with it constantly, and it is almost certainly not a bacterial disease, statements to the contrary resting upon evidence no careful mycologist or bacteriologist would for a moment be willing to accept.

At present peach yellows seems nearest allied to that phenomenon in plants known as variegation. It is now recognized that variegation in many plants (panachure) is a disease manifesting itself in stunted growth, imperfect assimilation, hastened development, and feeble vitality.* Moreover, in a number of variegated plants, e. g., jasmines and abutilons, this condition is transmissible to healthy stocks by budding or grafting, in the same way as peach yellows. The difference in these cases appears to be one of degree rather than of kind.

PREVENTIVE MEASURES.

With our present knowledge the cure of peach yellows appears to be impossible. Many reported cures have been investigated and found without merit. The claims made in behalf of some of these were manifestly with intent to deceive; in other cases they were made in ignorance of the symptoms of the disease and of what constitutes a cure, and generally by people not familiar with peach-growing. Faithful trial has been made of various fertilizers containing important plant foods. With some of these, especially caustic lime and fertilizers containing nitrogen, it has been possible to make diseased trees put on a greener and more vigorous growth, sometimes mistaken for recovery, but all such trees have continued to show symptoms of the disease and have soon relapsed into feeble growth.

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*There is also, as in yellows, an abnormal ratio of the ash constituents, potash and phosphoric acid being in excess and lime deficient.

So far, therefore, as we now know the only thing which can be done is to cut out and destroy all trees as soon as any of the signs described on a previous page have made their appearance. It is best to burn the diseased trees, roots and all, if possible.

In confirmation of this belief in axe and fire, we have the experience of the Michigan peach growers. In some localities, notably at South Haven, they have been fighting the disease in this way for the last twenty years, and though the extermination of affected trees has not been complete the results have been of such a nature as to lead the growers to believe that this annual weeding out has saved the orchards. Of several facts there can be no doubt, and it is difficult to draw from them other than one inference. First, this disease appeared at South Haven as long ago as 1869 in a few trees of a single peach orchard, becoming generally disseminated within five years and so destructive as to seriously threaten the prosperity of the peach growers. Second, the disease has not given serious trouble since the growers first began to wage their war of extermination, the extent of the orchards to-day being greater than formerly and their health and productiveness unimpaired. Third, there have been cases of yellows in this region every year since its first appearance, and the diminished prevalence is not easily attributable to other agencies, because in neighboring localities, where no effort has been made to stay its progress, the disease has prevailed extensively during this period, even to the destruction of all the orchards and the abandonment of peach culture in some regions. Even at South Haven there is evidence that a few years of general neglect would result disastrously, one or two men in recent years having neglected or refused to destroy affected trees, and the orchards immediately surrounding these having subsequently shown a larger number of cases than those in other parts of the district.

At South Haven and other places where the law is maintained it is customary to keep the orchards full by planting young trees in place of those removed. There are many such trees now in bearing and entirely healthy, although set in the very places occupied by diseased trees, and only a few months after their removal. Such "replants" sometimes develop yellows, but from an experience of many years the growers have learned that the disease does not show any decided preference for such trees. They are not immediately attacked and are not more subject to it than others. At St. Joseph, Mich., where yellows appeared in 1866, and all of the orchards were finally destroyed, many new orchards cover the old fields. These have been planted during the last ten years and many are now in bearing. Nearly all of these trees are healthy and the cases of yellows that have appeared in the last few years are apparently attributable to neglect of destroying old cases rather than to any inability of the soil to bear healthy trees. It must be said, however, that there has not been here that general interest in the subject which is manifest at South Haven. There have been a few cases of yellows in a good many orchards, and there is every reason to think that history will soon repeat itself in Berrien County unless the law is rigidly enforced.

As was pointed out some years ago, the chief defects of the Michigan law are, (1) the inadequate compensation given to the commissioners, not enough to be certain of commanding the services of well-qualified men; and (2) the want of a general superintendent who shall see that records are kept and be responsible for the enforcement of the law in all parts of the State. Both of these defects are remedied in the Connecticut law (see Appendix), and the work of combating the disease seems to have started off in that State with a vigor and thoroughness that is commendable, 283,782 trees having been inspected and 28,647 condemned in 1893.

The results of the rooting-out process obtained in other States than Michigan are less striking, either because the laws have not been enforced very generally or because they have been in operation only a short time.

The greatest difficulty in the way of enforcing a law of this kind is the desire on the part of owners to market fruit from affected trees. This opposition disappears as soon as it is made a misdemeanor to sell such fruit or buy it for sale, and consequently a clause of this kind should form part of all yellows laws. Provision should also be made in such laws for the destruction of diseased trees occurring in waste places and in villages and cities. It is important also that records should be kept each year of the number of trees examined and the number destroyed, so that in the future there may be a sounder basis for judgment as to the efficacy of the law.

By way of prevention several different lines of procedure have been suggested. Notable among these is the return to the soil of plant foods supposed to have been exhausted to such a degree as to induce yellows. In view of the wide distribution of this disease and its occurrence on a great variety of soils, this seemed hardly probable, although supported by some men of acknowledged ability. This view must now be abandoned, a comprehensive series of experiments planned to settle this question and continued over a period of four years having shown conclusively that blocks of trees heavily fertilized and making a rapid growth are not secure from the disease, but are quite as likely to be attacked as those left untreated.* In some of these experimental orchards the cases increased with an increasing number of treatments or became more speedily numerous on the treated portions, while in none of them, even when great quantities of fertilizers were used, was there any indication that the progress of the disease was stayed. These treatments were made in Maryland and Delaware. They included the use of lime, wood ashes, kainit and muriate of potash, dissolved boneblack and bone ash, nitrate of potash, nitrate of soda, sulphate of ammonia, tobacco dust, guano, dried blood, and stable manure. They were conducted in fifteen orchards, embracing more than 16,000 trees, and the trees under actual treatment covered an area of over 40 acres, occupying a variety of soils. It is necessary, therefore, to consider other expedients.

Some have held that the trouble originates exclusively in the nursery, and that the renewal of the orchards with trees having a "healthy constitution" would soon put an end to the ravages of the disease. Time, however, has shown that neither untainted buds nor sound stocks afford any considerable protection. This is true even when an earlier fall of the leaves and ripening of the wood is secured by working the peach upon plum or apricot stocks. In one of the Department experiments buds were taken in a region free from yellows, were worked upon well-rooted Marianna plum cuttings, and after a year's growth were set out in localities much subject to yellows. Most of these trees grew well for two or three years, but then began to die, some with symptoms of yellows and others from a want of proper union between stock and root. There could have been no constitutional taint in these trees, because the parent trees were kept under observation four years, during which time they remained free from disease, as did also the plums from which the cuttings were made, and all other peach trees in that vicinity.

PEACH ROSETTE.

DISTRIBUTION.

The rosette exists in the vicinity of Manhattan, Kans., in many parts of northern Georgia, and in a small part of western South Carolina, as shown approximately on the map accompanying this bulletin. It has also been reported from Arkansas. This disease occurs in peaches and almonds, and something very similar, if not identical, is common in plum trees, both wild and cultivated, but what is here detailed relates only to the peach.

The disease seems to have been present in Georgia only about fifteen years. If it occurred longer ago there is no conclusive evidence of it, and certainly it did not attract general attention or cause uneasiness until quite recently. During the last five or six years it has destroyed many trees in Georgia and is now present in more than twenty counties of that State, being common not only in budded and seedling orchards, but also in seedlings growing in the fields and by the wayside.

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* Bull. No. 4, Division of Vegetable Pathology.

DISTINGUISHING CHARACTERS.

Rosette clearly belongs to the same type of disease as yellows, but its first stages are more striking and its progress is much more rapid. It may first attack part of a tree and then the remainder, the same as yellows, but it is more likely to appear at once in the whole tree and generally in early spring. In trees attacked in this manner all of the leaf buds grow into compact tufts or rosettes. These rosettes, although seldom more than 2 or 3 inches long, usually contain several hundred small leaves. One of these rosettes is shown in fig. 5, and the appearance of the whole tree at the end of June is shown in fig. 6. A tree thus attacked always dies the following autumn or winter. When part of a tree is first attacked that part dies as above described, and the remainder shows symptoms the next spring, to die in turn after about six months.

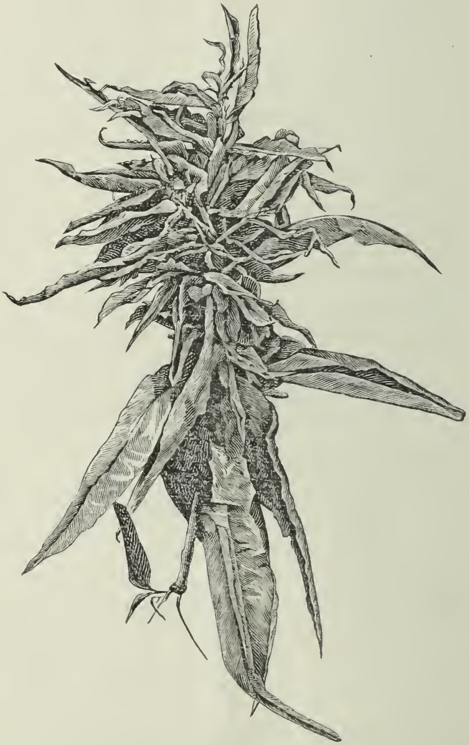

FIG. 5.—A single rosette.

The prevailing color of the foliage is yellowish green or olivaceous. The older leaves at the base of the tufts are largest and frequently grow to a length of several inches, but have inrolled margins and a peculiar stiff appearance, due to the fact that they are straighter than healthy leaves. These outer leaves turn yellow in early summer and drop as readily as though it were autumn, while the inner leaves of the rosette are still green and delicate. The compact bunching of the leaves is very conspicuous and makes the trees look quite unlike those affected by yellows. Where a tree is attacked in all parts it matures no fruit. In all the cases which have been noticed the fruit borne by affected trees either shrivels while green and drops off or else ripens naturally. No premature peaches have been seen in Georgia except such as were due to the girdling of the trunk by borers.

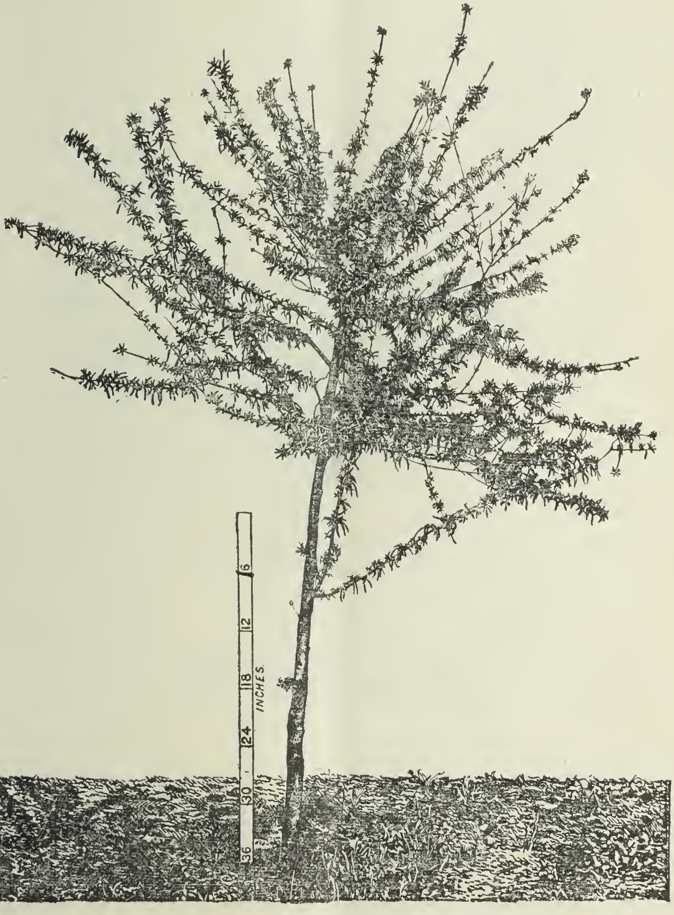

FIG. 6.—A budded tree attacked in spring and photographed in June.

In the absence of premature, red-spotted fruit, in the severity of the disease from the outset, and in its very rapid progress it is quite unlike yellows, which is decidedly chronic, and the first slight symptoms of which usually occur in very green and thrifty trees and are frequently overlooked the first season.

HOW SPREAD.

The rosette is readily and quickly communicated either by bud inoculation or by root-grafting. The only difference in the latter case is that the disease requires a somewhat longer time for its appearance in the top of the tree. In Department experiments carried on in Georgia the first slight symptoms appeared in many stocks soon after the insertion of the diseased buds, i. e., within two months, while in less than a year more than 100 trees became diseased in all parts, as shown in fig. 7.

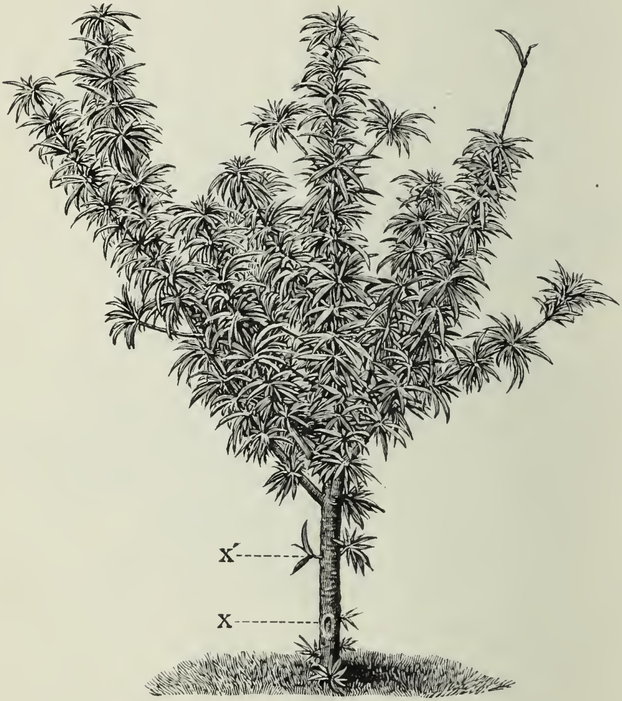

FIG. 7.—Rosette induced in a seedling by inoculation.

Two diseased buds were inserted into the trunk of this tree, at the points indicated (X and X′), June 21, and the photograph was made on June 6 of the following year. A curious fact in connection with this experiment is that 4 trees out of 125 entirely escaped infection. These were like the rest, except that the diseased buds which had been inserted into their trunks failed to unite. Their immunity was consequently attributed to this fact, and subsequent experiments confirmed the belief, showing that simple contact is not sufficient, but that, as in the case of yellows, there must be an organic union between the diseased tissue and the healthy stock in order to transmit the disease. It is surprising, however, how small a fragment will convey the disease if it can be induced to unite with the stock. Other methods of spread are not known, but such must certainly exist. In view of the failure to induce the disease by simple contact of diseased tissues with healthy ones, even when this was prolonged and close, it does not seem likely that the contagion is carried by birds or insects, and it is therefore possible that the disease may enter through the roots. Experiments have shown conclusively that the virus of this disease requires a period of some months to penetrate into all parts of a tree, and that its internal movement is manifested within a few months by external symptoms. This is true both of trees infected artificially and of those which contract the disease naturally. In the former the symptoms first appear near the inserted bud, and subsequently in remoter parts of the tree. In the latter, when the disease is severe on one side of a tree, the tissues on the other side may still be entirely free from it. This was suggested by the fact that the top on one side of a tree often seemed entirely healthy, while the other side and the whole base were badly diseased, and it was shown to be true by the removal of buds, which were grafted on plums and grew into healthy trees, while the disease passed over into the parent limbs and affected all parts the following spring.

PREVENTIVE MEASURES.

What has been said respecting the prevention of yellows applies also to rosette. Nothing is known as to the cause of this disease, but the same remark applies to such dangerous contagious diseases as smallpox and hydrophobia, and the time has certainly passed when such an objection can be urged as a good reason for inaction.

All diseased trees should be dug out and burned. This ought to be done in the spring, as soon as the rosette can be detected, owing to the fact that the leaves fall very readily in midsummer and are possibly a means of spreading the disease. Particular care should also be taken to destroy rosetted trees occurring on the borders of forests and in waste places generally, and, of course, in any thorough work of this kind the plum should be included, although not enough cross-inoculations have been made to put the identity of the plum disease and rosette entirely beyond doubt. The disease is virulently contagious, and, as in the case of yellows, if peach-growing is to continue successful for any great length of time in infected regions, it can be only by means of a well-directed, vigorous, and united effort.

APPENDIX.

THE CONNECTICUT YELLOWS LAW.

AN ACT providing for a commission on peach yellows.

[General Assembly, January session, A. D. 1893.]

Be it enacted by the Senate and House of Representatives in general assembly convened:

SEC. 1. The State board of agriculture shall, within thirty days from the passage of this act, appoint a commissioner on peach yellows, to hold office during the pleasure of said board. Said commissioner may, with the approval of said board and under the provisions of this act, adopt and carry out such plans as may be deemed necessary for the eradication of the disease, common to peach trees, known as peach yellows.

SEC. 2. At all joint meetings of said board and said commissioner, for the purpose of conference, the commissioner shall receive pay from the board for his expenses only. Said commissioner may, with the approval of said board, appoint one or more deputies in each county; and when employed in the performance of duties imposed by this act, said commissioner and his deputies shall receive from the State, upon presentation to the comptroller, of bills duly sworn to, audited by the auditing committee of the board of agriculture, and approved by the Governor, five dollars per day and their expenses.

SEC. 3. Any peach, almond, apricot, or nectarine tree diseased by the yellows, and all fruit from any such diseased tree, is hereby declared a public nuisance, and it shall be the duty of said commissioner or any deputy, under such regulations as the State board of agriculture may adopt or approve of, to order such trees or such fruit destroyed, and upon the failure of the owner to obey such order, to destroy such trees or fruit, and no damage shall be paid to such owner on account of such destruction.

SEC. 4. Any person may, when ordered to destroy any tree or fruit condemned by the said commissioner or deputy, appeal to the State board of agriculture, and said board shall appoint a committee of three experts, which committee shall not include the person who, acting as commissioner or deputy, ordered such tree or fruit destroyed, and the decision of such committee shall be final.

SEC. 5. Any person who shall, while such an appeal is pending, sell any tree from a nursery where there are found to be diseased trees, or any fruit from such tree; or who shall, without such appeal, or after such final decision, refuse to destroy such tree or fruit, shall be fined not less than one hundred nor more than five hundred dollars.

SEC. 6. Any person that shall knowingly buy, for the purpose of selling, or shall sell or offer for sale, any fruit from such diseased trees, shall be fined not less than ten nor more than one hundred dollars.

SEC. 7. For the purpose of investigation or for the purpose of destroying trees or fruit known to be diseased, the said commissioner and his deputies may enter any premises; and any person who shall prevent or attempt to prevent such entry shall be punished by a fine of not less than ten nor more than one hundred dollars, or imprisoned in a common jail not less than ten nor more than sixty days, or both.

SEC. 8. Prosecutions for violation of this act may be brought before justices of the peace, or any city, borough, town, police, or common pleas court having criminal jurisdiction, by any prosecuting officer, or by the commissioner on peach yellows, or any of his deputies, and for such purpose said commissioner and his deputies shall have all the powers of grand jurors.

SEC. 9. This act shall take effect upon its passage.

Approved June 14.

THE PENNSYLVANIA YELLOWS LAW.

AN ACT to prevent the spread of the disease in peach trees known as the yellows.

SEC. 1. *Be it enacted, etc.,* That it shall be unlawful for any one to knowingly or willfully keep any peach, almond, apricot, or nectarine tree infected with the contagious disease known as the yellows, or to offer for sale or shipment or to sell or ship to others any of the fruit thereof; both tree and fruit so infected shall be subject to destruction as public nuisances as hereinafter provided, and no damages shall be awarded in any court in this State for entering upon premises and destroying such diseased trees and fruit, if done in accordance with the provisions of this act; and it shall be the duty of every person, as soon as he becomes aware of the existence of such disease in any tree or fruit owned by him, to forthwith destroy or cause the same to be destroyed.

SEC. 2. In any township, borough, or city of this State in which such contagious disease exists, or in which there is good reason to believe it exists or danger may be justly apprehended of its introduction, as soon as such information becomes known to any supervisor of such township or to any highway or street commissioner of such borough or city, it shall be the duty of said supervisor, highway or street commissioner to appoint forthwith, three competent freeholders of said township, borough, or city as commissioners, who shall hold office during the pleasure of said supervisor or highway or street commissioner, and such order of appointment and of revocation shall be entered at large upon the records of such township, borough, or city.

SEC. 3. It shall be the duty of said commissioners, within ten days after appointment as aforesaid, to file their acceptance of the same with the clerk of said township, borough, or city, and said clerk shall be *ex officio* clerk of said board of commissioners, and he shall keep a correct record of the proceedings of said board in a book to be provided for the purpose, and shall file and preserve all papers pertaining to the duties and actions of said commissioners or either of them, which shall be a part of the records of said township, borough, or city.

SEC. 4. It shall be the duty of the commissioners or any one of them, upon or without complaint, whenever it comes to their notice that the disease known as yellows exists or is supposed to exist within the limits of their township, borough, or city, to proceed without delay to examine the trees or fruit supposed to be infected, and if the disease is found to exist, a distinguishing mark shall be placed upon the diseased trees and the owner notified personally or by a written notice left at his usual place of residence, or if the owner be a nonresident, by leaving the notice with the person in charge of the tree or fruit, or the person in whose possession said trees or fruit may be. The notice shall contain a simple statement of the facts as found to exist, with an order to effectually remove and destroy, by fire or otherwise, the trees so marked and designated, within ten days, Sundays excepted, from the date of the service of the notice, and in case of fruit so infected, such notice shall require the person in whose possession or control it is found to immediately destroy the same or cause it to be done. Said notice and order shall be signed by the full board of commissioners.

Sec. 5. Whenever any person shall refuse or neglect to comply with the order to remove and destroy the trees marked by the commissioners as aforesaid, it shall become the duty of the commissioners to cause said trees to be removed and destroyed forthwith, employing all necessary aid for that purpose; the expense of such removal and destruction of trees to be a charge against the township, borough, or city, and for the purpose of said removal and destruction the said commissioners, their agents and workmen, shall have the right and power to enter upon any and all premises within their township, borough, or city.

Sec. 6. If any owner neglects to remove and destroy or cause to be removed and destroyed as aforesaid, such diseased trees and fruit after such examination and notification and within the time hereinafter [hereinbefore] specified, such person shall be deemed guilty of a misdemeanor, and punished by a fine not exceeding ten dollars, or by imprisonment in the county jail not exceeding ten days, in the discretion of the court; and any justice of the peace of the township or borough, or any alderman in any city of this Commonwealth where such fruit is sold, shipped, or disposed of as aforesaid shall have jurisdiction thereof.

Sec. 7. The commissioners shall be allowed for services under this act, two dollars for each full day and one dollar for each half day for the time actually employed, and other reasonable charges and disbursements hereunder, to be audited, as well as any other charges and disbursements under this act, by the board of township auditors or the auditors of such borough or the controller of such city, to be paid to said commissioners as other township, borough, or city accounts are paid. Such fees and all reasonable charges and disbursements of said commissioners in each case, may be recovered by the township, borough, or city, in the name of the supervisor or highway or street commissioner, from the owner of the diseased fruit or trees on account of which such fees, charges, and disbursements became payable or were incurred.

Sec. 8. This act shall take effect immediately upon its approval by the Governor.

Approved the 26th day of May, A. D. 1891.

* * *

June 24 '95

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 18.

FORAGE PLANTS FOR THE SOUTH.

BY

S. M. TRACY, M. S.,
Director of the Mississippi Agricultural Experiment Station.

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Farmers' Bulletin No. 6. Tobacco: Instructions for its Cultivation and Curing. Pp. 8. Issued February, 1892.

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Farmers' Bulletin No. 18. Forage Plants for the South. Pp. 30. Issued August, 1894.

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Farmers' Bulletin No. 23. Foods: Nutritive Value and Cost. Pp. 32. Issued January 21, 1895.

Farmers' Bulletin No. 24. Hog Cholera and Swine Plague. Pp. 16. Issued December 12, 1894.

Farmers' Bulletin No. 25. Peanuts: Culture and Uses. Pp. 24. Issued February 9, 1895.

Farmers' Bulletin No. 26. Sweet Potatoes: Culture and Uses. Pp. 30. Issued March, 1895.

Farmers' Bulletin No. 27. Flax for Seed and Fiber. Pp. 16. Issued March, 1895.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., May 22, 1894.

SIR: I have the honor to transmit herewith for publication as a Farmers' Bulletin an article on forage plants especially adapted to the Southern States. This article was prepared by Prof. S. M. Tracy, Director of the Mississippi Agricultural Experiment Station, who had charge of the experiments with forage plants carried on during the past five years by this Department in coöperation with the experiment stations in Mississippi, North Carolina, Georgia, Florida, and Louisiana. Over 500 native and foreign species of grasses and other forage plants were tested with special reference to their value for hay or pasturage. This bulletin summarizes the practical results of this investigation, and is confined to accounts of the species whose value for the agriculture of the South has been definitely established.

The illustrations were prepared under direction of Prof. F. Lamson-Scribner of this Department, some of them having been previously furnished by him to the publishers of Webster's International Dictionary, by whose courteous permission they are used in this publication.

Respectfully,

A. C. TRUE,
Director.

HON. J. STERLING MORTON,
Secretary of Agriculture.

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FORAGE PLANTS FOR THE SOUTH.

The soil, climate, and conditions of the Southern States are so different from those of the North that different species of plants, as well as different methods of culture and treatment, are necessary to success in the making of meadows or pastures. The soil, although almost wholly of sedimentary formation, is exceedingly variable in character. Much of it has had nearly all of its vegetable matter exhausted by continuous cultivation in cotton. In many sections extreme care is necessary to prevent the washing of hillsides. Severe freezes are unknown, so that many of the more hardy plants continue their growth during the entire winter. On the approach of hot weather these plants disappear, and their places are filled by a rank summer growth of plants, many of which are too coarse and unpalatable to be of value for either hay or pasture. Although the growing season is almost continuous for some species, there are none which will make a vigorous growth throughout the year, so that permanent meadows and pastures can be made only with mixtures of several species which make their growth at different seasons.

Sufficient hay for home consumption may be gathered on almost any plantation without expense, except for the harvesting, but such crops are uncertain in amount, are usually inferior in quality, and are rarely such as will assist in preparing the soil for future crops. A good hay plant must not be too rank in its growth, or its stems will be coarse and woody; it must have a large proportion of leaves, which are the most edible parts of the plant; it should be easily cured when made into hay; and it must be nutritious, easily digested, and palatable. If wanted for a permanent meadow, the plant must be a perennial. As the true grasses are of but little value as fertilizers, it is important that, where the crop is to be grown as a part of a rotation, at least one of the species used in any mixture should be a leguminous plant; if the forage crop is to be grown one season only, leguminous plants are always to be preferred.

FORAGE CROPS FOR DIFFERENT SOILS.

No one grass or mixture of grasses will be found best for all localities, but the choice must be varied to meet local conditions. The character of the soil is the principal item to be considered in making a selection for sowing. In the region covered by this work there are four types of soils, which embrace fully nine tenths of its area. These are (1) the yellow loam and clay uplands, (2) the alluvial river bottom lands, (3) the black prairie regions, and (4) the pine woods region. For each of these sections different species, different mixtures, and different modes of treatment are required; and this Department has made a special study of the requirements of each region.

YELLOW LOAM SOILS.

The yellow loam and clay uplands include a large part of North Carolina and the northern portions of Georgia, Alabama, and Mississippi. They are also found in northern Louisiana and in some parts of Texas, where they merge into the pine woods lands. The land in the western part of this region, from Mississippi to Texas, is mostly rolling and well drained, contains an abundance of lime, and is naturally very fertile, but often hard and compact, containing but little sand, and suffering severely from drought. In the eastern section the soil generally has less lime, is much lighter and more sandy, and so can be more easily worked. While the crop here is less in quantity than that from the bottom lands, it is superior in quality, being less coarse in fiber, richer in nutritive matter, and less mixed with weeds and coarse grasses.

Bermuda grass, Johnson grass, lespedeza (Japan clover), red clover, and melilotus furnish the principal hay crops of this region, and for a permanent meadow on rich soil Bermuda grass is undoubtedly the best species, though we have found no leguminous plant which is satisfactory for sowing on the same ground. Red clover is often sown on the same land with Bermuda grass, but as the two mature at different seasons, and as the clover is seldom permanent, the mixture can hardly be recommended. Bermuda grass meadows may be pastured through the winter without injury. Alsike clover adds greatly to their value at that time, and as it also increases to some extent the hay crop, it is perhaps the best of the family for sowing on Bermuda grass meadows. Johnson grass gives the largest yield, and if it were not for the ease with which it spreads to adjoining fields and the extreme difficulty with which it can be eradicated, we should recommend it highly. Melilotus is the best of the legumes for sowing with it, and as it increases the yield largely, makes the hay more palatable, and keeps the soil in better condition, it should be sown on all such meadows. When a crop is wanted to occupy the ground for two years only, red clover, as it yields well, should be sown on the rich soils that are in good condition, and in the South at the present time the hay sells better than that from any other crop. On the more sterile soils, which are not soon to be planted with other crops, lespedeza is perhaps the best plant which can be used, and on lands containing an excess of lime melilotus is the most profitable crop. When the land is to be used for only a single crop of hay lespedeza is the best for thin clay soils; while for fields in even fair condition cowpeas will be found the most profitable; and on very rich soils German millet may be grown to advantage. For soiling, sorghum, soja beans, and beggar weed do well.

About 165 species of grasses are native to this region, and many of these furnish large amounts of hay. Several species of broom sedge, *Panicum*, and *Paspalum*, and many other native species abound on the uncultivated lands, and if cut sufficiently early, before the seed stems are grown, make hay of fair quality; though if allowed to grow until the seed is ripe, as is too often done, they are of but little value for hay, being tough, wiry, and unpalatable.

The natural pastures in this region are all that can be desired during the summer and fall months, but fail rapidly after the first heavy frosts, and do not become really good again until April. For making a permanent pasture Bermuda grass and lespedeza are the best foundation; and to these should be added orchard grass, Hungarian brome, and bur clover for the drier soils; while redtop, water grass, and alsike clover will be the best additions for the wet lands. White clover grows well on the uplands, and the Carolina and creeping clovers give rich grazing in March and April, but soon disappear. On the sandy and gravelly uplands, especially on the Atlantic coast, crimson clover gives excellent winter pasture, and under continuous grazing will reseed the ground so as to be practically permanent. Where crimson clover will not grow and the pasture is needed for immediate use, rescue grass, Terrell grass, and hairy vetch will make good winter pastures; and if stock be taken from the field in March or April these plants will reseed the ground for the following season, but they will soon disappear under continuous grazing.

One of the most common pests in the upland pastures of this region is the bitter weed (*Helenium tenuifolium*) which is eaten freely by cows in the absence of better herbage and which imparts a very disagreeable flavor to their milk. The presence of this weed is an almost certain indication that the soil is weak and thin, and that the land has been pastured too closely. Such pastures can be easily recuperated by resting and fertilizing, as the weed is never troublesome on lands which are rich and in good condition.

ALLUVIAL AND RIVER BOTTOM LANDS.

The river bottom lands are found along the courses of all the larger streams in the eastern section, and cover a large portion of western Mississippi, southern Louisiana, and eastern Texas. These soils are almost wholly of recent alluvial formation, are rich in humus, and usually contain an abundance of lime, together with more or less sand. Many of them are subject to overflows and nearly all of them suffer from want of drainage. Being more fertile than the uplands they produce larger crops of hay and afford a much wider range of choice in the selection of varieties.

For permanent meadows on these lands Bermuda grass, Johnson grass, redtop, alfalfa, and red clover all do well, though Bermuda grass and red clover have given the most general satisfaction. Of the true grasses, Bermuda grass makes hay of the best quality. Its yield is from 3 to 4 tons per acre in two cuttings, and it is not injured by short overflows. Johnson grass also yields heavily but it is more easily injured by water than is Bermuda grass, and the hay does not sell as well. Redtop bears a longer overflow than does either of the others, and we have found it advantageous to sow it on places where the others are liable to be drowned out, as it adds largely to the yield of hay and keeps down the growth of weeds and coarse grasses. Where the soils are fairly well drained red clover does well and is one of the best crops which can be grown, as the hay finds a ready market at good prices. On soils which have thorough drainage alfalfa makes a heavier yield than any other good hay plant, but it can not be grown profitably on heavy soils or where standing water comes near the surface. When a meadow is wanted for two years only, red clover is by far the best plant that can be used, while if but a single crop is to be cut, lespedeza is best, especially for the drier soils, in which it can be sown early; and for late sowing German millet has given the best results. For soiling crops we have found nothing better than teosinte, alfalfa, and soja beans.

It is comparatively easy to make good summer pastures with Bermuda grass and lespedeza on these lands, but in the winter the soil becomes so water-soaked and cold that it is difficult to find plants which afford good grazing during that season. In all these regions canebrakes are more or less abundant and furnish rich feed, but are usually so scattered that they can do little more than sustain life in the animals which range through them. Bermuda grass makes the best of summer pasture, but is killed to the ground by moderate frosts and so is of little value during the winter. Johnson grass lasts but a short time when pastured, and red clover is soon trampled out. Redtop is much more lasting and should be sown in every field intended for a permanent pasture. Alsike clover does well on these soils even when heavy and badly drained, and is the best of the family for winter grazing. Bur clover also does well, and alfalfa makes good winter pastures on sandy soils in the extreme South. Japanese rye and rescue grasses grow well where they are not subject to overflow, the former being the more permanent. Among the native sorts that can be grown here to advantage are the large water grass and Terrell grass, both of which grow during the cooler months and are unhurt by overflows. Carpet grass will make good winter grazing where the soil is dry and sandy. Where pastures are wanted for one season only we have found nothing better than a mixture of Terrell grass, perennial rye, and hairy vetch sown in August or September for winter use; with lespedeza, beggar weed, and Mexican everlasting grass for summer use.

THE BLACK PRAIRIE REGION.

The black prairie soils are found principally in western Alabama, eastern Mississippi, and eastern Texas, but though among the most fertile in the whole country they need peculiar treatment to make them productive. While ordinary commercial fertilizers and even liberal applications of stable manure produce little effect on them, the plowing under of an occasional green crop seems all that is necessary to keep them in a state of high productiveness. Most of these lands are quite level, are poorly drained, and remain wet very late in the spring, but pulverize readily when dry, even though they have been plowed while quite wet. They are rich in lime, and no better grass lands can be found.

For the production of hay alone, without regard to its effects on the soil, Bermuda is the best grass which can be grown as a permanent meadow. Under proper management, however, these lands are so productive for corn and cotton that most planters prefer to rest the fields with some crop which will give prompt returns in hay and which will at the same time prepare the soil for some future hoed crop. For this purpose, on these soils, there are no plants equal to melilotus and red clover, the former being the more valuable as a fertilizer, while the latter makes the better hay. On soils which contain an excess of lime, are badly drained, or are in poor mechanical condition melilotus will grow well, give fair returns in hay, and do more than any other plant to put the soil in good condition; while on the better soils red clover is more profitable for hay, and gives to the soil all the green manuring which it needs. Johnson grass also does well here, and a mixture of this grass with melilotus, recommended on another page, makes a heavy yield of excellent hay. Lespedeza grows well on the soils which are not too wet, and is perhaps the best hay crop which can be grown where the field is to be used for that purpose only one year. For a short-season hay crop to follow wheat, oats, or potatoes, either cowpeas or German millet should be used.

There is a variety of sorghum, commonly known as "chicken corn," which has become thoroughly naturalized on the black prairie lands of Alabama and Mississippi, and which is a valuable addition to the hay-producing crops. It is doubtless descended from some of the numerous varieties which the Department brought from China about thirty years ago, and in general appearance it is much like the common broom corn, though the heads are less spreading and the stalk usually branches at several of the upper joints. It is common in cornfields, starting up late in the summer, after the crop has been laid by; its growth is rapid, and in September many fields appear as though planted with common sorghum. If cut before heading it makes fair hay, and on rich soil will produce a heavy second crop. If allowed to mature the yield of seed is about the same as that of the ordinary cultivated varieties, and is worth about as much for feeding stock.

As in most other parts of the South, Bermuda grass and lespedeza furnish an abundance of summer grazing in this region; but it has been more difficult to find satisfactory plants for winter pastures here than for any other soils which the Department has investigated. Melilotus is thoroughly at home on these soils, and in nearly all localities has been so satisfactory that little else seems to be needed. Alsike clover grows well on the heavier soils, but soon disappears from the ridges and looser soils. Hungarian brome grass, orchard grass, and redtop are the best of the true grasses for general use, while Texas blue grass has done well in a few localities. Bur clover and hairy vetch succeed admirably where the soil is fairly dry, but neither will grow where the ground is wet for considerable periods of time.

THE PINE WOODS REGION.

The pine woods region reaches from 50 to 150 miles back from the coast, and extends in an unbroken line from Carolina to Texas, except where interrupted by the mouths of the larger rivers. The soil is usually a sandy loam containing but little lime, and underlaid with a heavy clay subsoil. Where the woods are open native grasses flourish in great abundance, and thousands of cattle and sheep are raised which never see a pound of hay or grain, though the living which such animals get is a hard one, the beef being poor in quality and the wool light in yield. Here hay-growing is of less importance than farther north, but it has become generally recognized that, although animals may live through the winters on the native pastures, it is more profitable to shelter and feed them during the heavy winter rains, and that an occasional hay crop is a cheaper and better fertilizer than can be secured in any other way.

On ground which has been well fertilized Bermuda is the best grass for permanent meadows, but a majority of the planters in this region, where the growing season lasts nearly twelve months, find it more profitable to make hay upon lands from which some other crop has been harvested, and in many cases the hay is secured for the bare cost of gathering. Along the Gulf coast crab grass and Mexican clover form the bulk of the hay crop. Both of these plants "come in" on the cultivated lands, and both make a heavy spontaneous growth late in the season, maturing at the same time, and if cut before becoming too ripe making most excellent hay. Alfalfa does well where the soil is sufficiently fertile, and has proved remarkably successful on some of the drier lands of Florida. On the Atlantic coast crimson clover is one of the best of hay plants, and its introduction is making great changes in the hay-growing practice of that region. Dr. Battle, who has had charge of the Department work in North Carolina, says of it: "Hay made from the crimson (scarlet) clover stands out frequently as the richest of foods. It leads pea-vine hay, lucern, red clover, timothy, redtop, alsike clover, and orchard grass." Timothy and red clover also do well in North Carolina, and in many localities Johnson grass is highly valued.

When the crop is wanted for its fertilizing effect as much as for its hay, the cowpea is the best plant that can be grown. If sown early two crops can be made during the season, and if not sown before August the vines will still have time to cover the ground with a dense growth which can be cut for hay, pastured, or left to decay on the ground, at the convenience of the planter. Lespedeza makes heavy crops on such of these soils as contain a small amount of lime; but melilotus has not been generally successful.

For winter pastures in the Atlantic coast region, crimson clover is valued highly, as it makes both winter pasturage and a winter growing fertilizer, being one of the few plants which can be used for this double purpose. Japanese rye and orchard grasses also succeed well there, and in some localities Texas blue grass has done well. In Florida the best winter pastures have been made from alfalfa and Texas blue grass; while along the Gulf coast carpet grass and the large water grass have been more valuable.

FORMATION AND CARE OF PASTURES.

Preparation of the land.—The ground should be well plowed only a few days before the seed is to be sown, and then harrowed until the surface is thoroughly pulverized and smoothed. If hard and full of clods, a disk harrow is the best thing we have found for pulverizing the soil, and it should be used as soon as possible after the plowing is done before the clods have time to bake. The last harrowing should be done with a Thomas or some similar harrow in order to leave the surface as smooth as possible.

Small and heavy seed, like clover, can be sown more evenly with a "wheelbarrow seeder," of which there are several kinds in the market, than with any other implement we have used; but for sowing coarser seeds, like Johnson grass, or chaffy seeds, like those of orchard grass, we have found no machine which has been satisfactory, and we prefer to sow such seeds by hand. Light and heavy seeds should always be sown separately, as it is practically impossible to keep them evenly mixed, and in sowing by hand the heavy seeds will be thrown so much farther than the light that the field will be streaked and irregular. When the sowing is done by hand we prefer to go over the field twice, using half of the seed each time and making the second sowing at right angles to the first.

For covering the seeds we prefer a heavy roller to any other implement, as it covers them more thoroughly and presses the soil about them so firmly that fewer are lost by rains and drought. If a roller is not to be had, a light smoothing harrow or even a brush may be used, but a heavy harrow should never be used except for covering very coarse seeds. When the ground is in good condition, freshly harrowed, and loose, and the seed can be sowed just before a rain, covering is scarcely necessary, and we prefer to omit it altogether rather than to use a heavy harrow.

Time of sowing.—In the South nearly all perennial grasses and clovers will do better if sowed in August or September than at any other time, as they then become well established before the winter frosts, and are ready to make such a vigorous growth early in the spring that they will keep down the weeds and volunteer grasses which so often choke out the spring sowings. Some of the more hardy species will do well if sown as late as October or November, though even for these the earlier sowing is preferable. If the land has been occupied by other crops so that fall sowing is not practicable, the work should be done as early in the spring as possible that the young plants may become well rooted before the summer drought. It is seldom advisable to sow with grain.

Application of fertilizer.—No satisfactory crops of hay can be made to grow on soils too exhausted or too barren to produce fair crops of corn or cotton, and fertilizers are as necessary and as profitable for the hay field as elsewhere. The use of fertilizers is more important for meadows than for pastures, from the fact that droppings from the stock will in a great measure compensate for the material carried away; but when pastures have been used so long that the ground has become hard, and the more tender plants have been killed out by trampling and close grazing, it will pay well to plow, fertilize, and reseed the ground.

Stable manure and cotton seed are the best fertilizers for plowing under before the seed is planted, and a liberal application of these will be all that is needed for two or three years; but on permanent meadows top-dressing must finally be employed to keep them in good condition. It is seldom necessary to use phosphoric acid on soils containing even a moderate proportion of lime; but all the true grasses are heavy consumers of potash and nitrogen, both of which it will pay to supply in liberal quantities. For ordinary soils 50 pounds of potash per acre is a liberal annual application, and this may be secured by using 400 pounds of kainit, 250 of cotton-hull ashes, or 100 of muriate of potash. Estimating the potash at the usual rate of 5 cents per pound, the relative value of these fertilizers per ton is as follows: Kainit, $12; cotton-hull ashes, $20; and muriate of potash, $50; but as the market prices are quite variable, the selection of the one for use will depend on their local cost. For soils which are deficient in lime, and where phosphoric acid is needed, the cotton-hull ashes have an additional value of about $9 per ton on account of the phosphoric acid which they contain, and for such soils these ashes are usually the cheapest fertilizer.

When phosphoric acid alone is needed, it may be purchased most cheaply in the form of acid phosphate. The cheapest form in which nitrogen can be purchased is as nitrate of soda or as cotton-seed meal, the former having about double the amount of nitrogen contained in the latter. The meal contains approximately 7 per cent of nitrogen, 3 of phosphoric acid, and 2 of potash, which makes it practically a complete fertilizer. It is one of the best materials we have for use as a top-dressing on grass lands.

It apparently makes little difference when phosphatic and potassic fertilizers are applied, but as the nitrogenous compounds are very quickly dissolved and lost, they should be applied only for immediate effect. If but one application is to be made it should be given when the grass is commencing its growth in the spring. The mixture which has given us the best satisfaction on grass lands containing lime has been equal weights of cotton-hull ashes and cotton-seed meal. For lands deficient in lime we use the same mixture, and add a separate application of acid phosphate early in the spring. Cotton-seed meal produces little effect on the clovers, and for such crops we have found a mixture of equal weights of ashes and land plaster most effective, adding the separate application of acid phosphate when the soil is deficient in lime.

We have found no machine which will distribute these fertilizers more evenly and economically than can be done by hand.

DESCRIPTION OF THE FORAGE PLANTS SUCCESSFULLY CULTIVATED IN THE SOUTH.

In tests of forage plants at the experiment stations the usual plan has been to make the first sowings of each species on small plats where they would receive all necessary care and attention, but even under these favorable conditions many species, especially of those received from India and Australia, failed to give satisfactory results and were discarded. Such species as succeeded well on the small plats were afterwards sowed in open fields, where they received only ordinary care, in order that their practical value might be fully shown.

The special characteristics and value of the most successful species are briefly stated below:

THE TRUE GRASSES.

Of the 364 species of the true grasses, as distinguished from the clovers and other forage plants which have been tested during the past five years, the following have succeeded best and seem to have the greatest value for cultivation in the South:

Japanese rye grass (*Agropyrum japonicum*).—In nearly every location where it has been planted this grass has done well. It is a perennial which resembles rescue grass, and like that species makes its best growth during the cool months. It is therefore valuable for winter grazing, but its yield is too small for hay. It does well on dry ground and makes a fair growth from November to March, after which it seeds freely and grows but little during the summer. It has done well at the Louisiana Station, where it begins its growth early in the fall and lasts until late in the summer; at the North Carolina Station it promises to hold its own with orchard grass; at the Georgia Station it has been less permanent, while in Mississippi it stands well on rich soil, but soon disappears from the poorer lands. Seed should be sown in August or September, at the rate of 40 pounds per acre. (Fig. 1.)

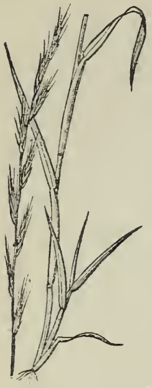
FIG. 1.—Japanese rye grass.

Redtop (*Agrostis alba*).—This has succeeded well in permanent pastures on all soils containing a fair supply of moisture, especially in Louisiana, on the river bottom lands, and on the "seepy" hills of the yellow-loam region. It will yield one cutting of hay, and by repeated mowings it may be made to hold its ground during the summer, but its chief value is as a part of the mixture of grasses for winter pasture. Its growth during the first season is rather weak and disappointing, but it strengthens and improves with age, holding its own well against other grasses and weeds, and is not easily killed by overflows, even when covered with water two or three weeks at a time. It does better on a clay soil than on one which is too sandy, and in favorable locations furnishes good winter grazing. There are several varieties of this grass which are much alike in general appearance, but the one known as "Rhode Island bent" or "creeping bent" forms the best sod, and is the one to be preferred for pastures. Seed should be sown early in the spring, at the rate of 25 pounds per acre if sown alone; but its growth is so weak during the first season that we have found it better to use from 15 to 20 pounds, and to mix it with from 30 to 40 pounds of perennial rye grass, as the latter makes a quick and vigorous growth which disappears at the end of the first season, when the redtop will cover the ground.

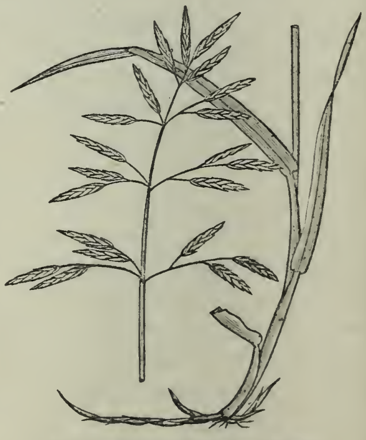
FIG. 2.—Hungarian brome grass.

Hungarian brome grass (*Bromus inermis*) (also called smooth brome).—This grass is a native of southern Russia, and endures our summer heat and drought much better than does its near relative, rescue grass, and, being a perennial, is much more permanent. It remains fresh and green during a larger part of the year than any other grass we have grown, with the exception of the large water grass, and, as it is at its best during the late fall and early spring months, it is especially valuable for winter pastures. In favorable locations it maintains itself well against other grasses and weeds, bears grazing well, and is not injured by moderate frosts. It produces a great amount of long tender leaves very near the ground, while the culms are slender and not numerous, so that it is better for grazing than for making hay. It covers the ground more evenly than rescue grass, and for grazing purposes is decidedly superior to that species. Like nearly all grasses it makes its best growth on rich soils, but even on rather thin and barren fields it is one of the best. Seed is produced very sparingly, and is hard to obtain in this country. It should be sown in February or March at the rate of from 30 to 40 pounds per acre. (Fig. 2.)

Rescue grass (*Bromus unioloides*).—This is a native of the western part of the United States, and was one of the first of our native species to be brought into cultivation, having been grown for many years under the names "Australian oats," "Schrader's brome grass," etc., and more recently under the name "Arctic grass." It is usually an annual, though if grazed closely or mowed frequently the roots will often live several years in rich and not too heavy soil. It makes the best growth during the cooler months, usually starting up in October or November, and continuing to grow until it ripens its seeds in April or May, after which little is seen of it until cool weather comes again, as it does not bear heat and drought. Its growth largely depends on the character of the season, and in favorable years it gives excellent pasture from November to May, while in other seasons it may make but little growth before February. On thin and dry soils its growth is small, from 12 to 15 inches, but on rich and somewhat damp soils it makes a growth of 3 feet or more, with a large proportion of leaves, which are tender, sweet, and nutritious, and which are renewed very quickly after being eaten down. If used for making hay, in a favorable season it will give a good cutting in February and another in April, and the third crop will make sufficient seed to stock the field for the next year. As its growth varies so much with different seasons it can hardly be relied upon for winter pastures, though it never fails to make an abundant growth early in the spring, and its chief value is for mixing with other plants like orchard grass, bur clover, and vetches. Along the Gulf coast its growth is less dependent on the seasons, and in Louisiana it is regarded as being one of the best winter grasses. Seed should be sown in August or early in September, at the rate of from 30 to 40 pounds per acre. (Fig. 3.)

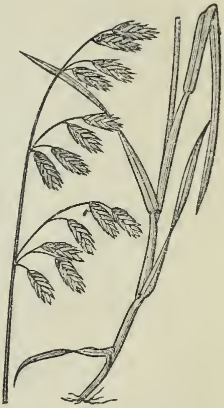

FIG. 3.—Rescue grass.

Orchard grass (*Dactylis glomerata*).—This has given a better winter growth on wet and heavy clay soils with ordinary field treatment than any other grass which we have tested. It is a perennial which commences its spring growth with the first warm days of February, and if not pastured, is ready to cut for hay in April, and will then afford excellent grazing until checked by the summer drought. With the first autumn rains it starts a new growth of leaves, making rich fall pasturage, and remaining fresh and green all through the winter. The hay made from it is of excellent quality, though its habit of growing in large clumps is against its use as a hay grass; but it bears grazing well and recovers quickly when cropped down. It does well when mixed with redtop, and succeeds better than almost any other grass in woodland pastures. Sandy soils are not suited to its growth, and it can not be recommended for any light and thin lands. Seed should be sown in August or very early in the spring at the rate of from 30 to 40 pounds per acre. (Fig. 4.)

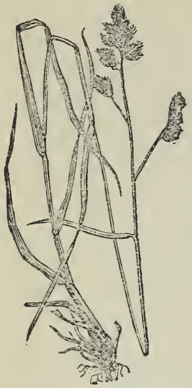
FIG. 4.—Orchard grass.

Terrell grass (*Elymus virginicus*).—This is a native perennial grass which has received little attention, but which is of considerable value for winter pastures. It grows most abundantly along creek banks, in fence rows, and on the borders of woodlands, but with proper care can be made to grow on almost any soil. This grass makes its best growth during the fall and winter months, and it is ready to cut in May, but the hay made from it is of inferior quality; its special value is for winter pastures. It commences its fall growth on the approach of cool weather, just before lespedeza is killed by frosts, and continues green and luxuriant until it begins to seed in April or May. Although a perennial, it is short lived under close grazing, and stock should be taken from the fields sufficiently early to allow it to ripen its crop of seed, which is produced in great abundance. The land on which it grows will give a crop of lespedeza during the summer, which may be pastured from June onward, and by the time the lespedeza is gone the grass will be ready for the fall and winter grazing. Experience with Terrell grass at the experiment stations indicates that, like rescue grass, it will be of considerable value under good management, though of little use when it fails to receive the proper attention. Seed should be sown in August at the rate of from 30 to 40 pounds per acre. (Fig. 5.)

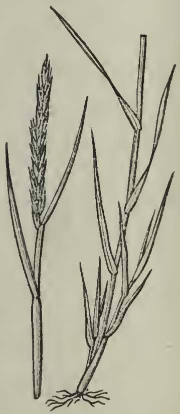
FIG. 5.—Terrell grass.

Teosinte (*Euchlæna luxurians*).—This plant needs a long season of hot weather, a rich soil, and abundant moisture in order to succeed well, and it is useless to plant it where all these conditions can not be had. It is a remarkably vigorous grower, reaching 10 or 12 feet in height, with an unusually abundant supply of leaves and slender stems which continue to grow until killed by frosts. If cut when it reaches 4 or 5 feet in height it makes excellent fodder, and will produce a second crop fully as large as the first. If left to grow until September or October it furnishes excellent material for the silo, in greater amount per acre than either corn or sorghum, and we have found no other plant which is its equal for soiling purposes. Its leaves are similar to those of sorghum, but much longer; the stalks contain from 8 to 10 per cent of sugar. The plants stool freely, sometimes as many as 50 stalks growing from a single seed. It has done fairly well at the Georgia and Mississippi Experiment Stations and very little in North Carolina, but has made a heavier crop than any other plant which has been grown at the Florida and Louisiana Stations In Mississippi the heaviest yield has been 22 tons per acre, while the Louisiana Station reports the enormous yield of over 50 tons of green forage per acre. Its value for feeding is apparent from the fact that the entire crop grown at the Louisiana Station was sold to local dairymen at the rate of $2 per ton while standing in the field. Its season of growth is so long that it seldom matures north of latitude 30 degrees, but it has ripened well at the Florida and Louisiana Stations. The seed, 4 to 5 pounds per acre, should be planted in hills 4 or 5 feet apart each way, about the time when cotton is planted, and the crop cultivated like corn. The greater distance should be given on the richer soils. (Fig. 6.)

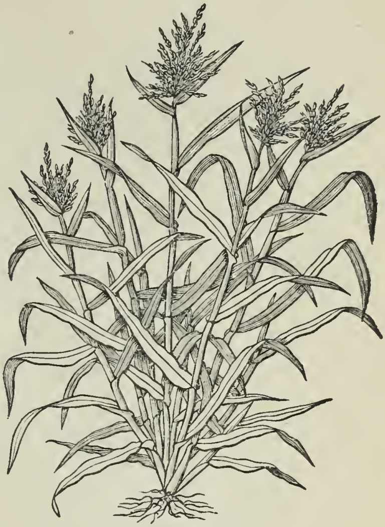
FIG. 6.—Teosinte.

Bermuda grass (*Cynodon dactylon*).—Bermuda grass is to the South what Kentucky blue grass is to the North, and is the best hay grass for all rich soils. It will grow well on any rich soil, whether wet or dry, but never makes a satisfactory growth on barren soils of any kind. In favorable seasons it will give two cuttings, and on good soils its yield is from 2 to 4 tons of hay per acre. Having very slender stems with an abundance of leaves it is easily masticated and is relished by all kinds of stock, being especially valuable for horses and mules, though of less value for calves and milch cows. When once established in a field it is somewhat difficult to eradicate, and this is sometimes an objection to its general cultivation. The best method of

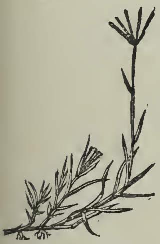
FIG. 7.—Bermuda grass.

destroying it is to plow the ground immediately after the hay is cut, leaving it as rough as possible. Plow again in November and sow to oats, and when that crop is harvested plow again and sow thickly with cowpeas, which will smother the few plants of the grass which may have survived the oats and will leave the land in the best possible condition for any future crop. As Bermuda grass rarely produces seed it is usually propagated by transplanting the roots. This may be done preferably when the ground is thoroughly wet and soft, at almost any time except in the winter months, and is not more expensive than is the seeding of the ground in the ordinary manner. Shave off sods an inch or two in thickness, cut them into pieces about an inch square and drop on the new ground about 2 feet apart each way, stepping on each one and crowding it well into the soft ground as it is dropped. If it is necessary to do the work when the ground is too hard for this method, one man can make small holes with a single stroke of a hoe, while another drops the sods and covers them with his foot. When the ground is in good condition and the sods convenient, one man can plant an acre in a day. Good stands can be secured in time by scattering a dozen or more sods to the acre and then cultivating the land in corn or cotton for two or three years, after which the grass will have become so well distributed that the field will need only to be plowed and harrowed smooth to make a good meadow. If the meadow is plowed and harrowed in the spring, once in from three to five years, the yield is greatly increased, and the grass responds very quickly to an application of fertilizer, especially stable manure. (Fig. 7.)

Perennial rye grass (*Lolium perenne*) (also known as Randall grass and English meadow grass).—For sowing with redtop and other slow-growing sorts when immediate results are wanted for either pasture or hay, this is one of the best varieties, but it will seldom make a permanent meadow or pasture, as it can not endure heat. It makes a quick and rapid growth, covering the ground well in a few weeks after sowing, and if sown in the fall it will give a good cutting for hay in April, after which little will be seen of it except in unusually favorable locations. It is important that the crop should be cut as soon as well grown, since if this is not done the warm rains of June and July cause the leaves to decay very rapidly and so smother the small plants of other grasses which may be growing on the same ground. On deep, rich river bottom lands, especially in Louisiana, it often holds its own for some years and will give two or three cuttings during each season, but this is not common, and it never lasts more than one season when closely pastured. Sow seed in October or February, at the rate of from 50 to 60 pounds per acre if sown alone, or half that amount if with redtop and other grasses. (Fig. 8.)

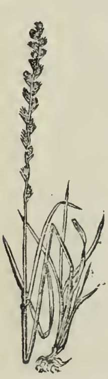

Fig. 8.—Perennial rye grass.

Guinea grass (*Panicum jumentorum*).—This is a native of Africa, and the Department first called attention to its value in 1873, when a considerable quantity of the seed was imported and distributed in the Southern States. It is a perennial which requires a long season for its growth, and since it ripens seed only in the extreme South it is more commonly propagated by dividing the roots. It has proved to be well adapted for cultivation on the sandy soils of Florida, especially on worn-out pine lands where few other grasses have given satisfactory results. When allowed to mature it grows from 8 to 10 feet high, but in order to secure satisfactory hay or forage for soiling, it should be cut when not more than 3 feet high, and it will furnish such a cutting every month or six weeks from April to November. Few plants will yield a greater amount of fodder, and for a region of only slight frosts and frequent rains it is one of the best forage crops we have. Plants should be set about 3 feet apart each way in March, or seed may be sown at the same time. (Fig. 9.)

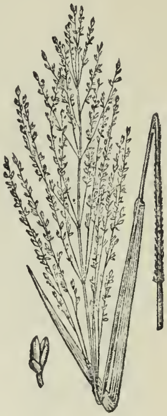
FIG. 9.—Guinea grass.

Crab grass (*Panicum sanguinale*).—In the Northern States this is regarded as a troublesome weed and wholly worthless, but in the South its character is very different. It makes a heavy spontaneous growth on fields from which wheat, oats, corn, or other early crops have been harvested, and on good soils will yield 2 tons per acre of hay, which, if cut before it is too ripe, is fully equal in value to timothy. In order to secure hay of the best quality it is essential that it be cut as soon as it is fully grown. On land which was plowed in February, and on which no other crop was grown, we have cut four crops of about 1 ton each per acre in a single season. As it makes its best growth late in the fall, and as the hay made from it costs nothing but the harvesting, it is valued highly. It makes its best growth on the sandy pine lands along the Gulf coast, where it furnishes three fourths of the hay, and where many of the planters say they wish for no better hay grass, as this is good in quality, inexpensive, and a sure crop. Mexican clover is usually found on the same lands, and as it is also a volunteer crop, growing at the same time with crab grass, it adds largely to the yield, and is claimed by many planters to improve the quality of the hay. (Fig. 10.)

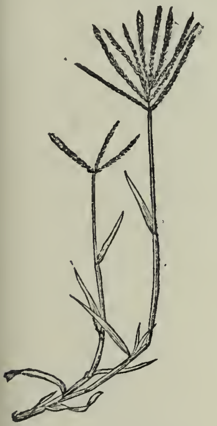
FIG. 10.—Crab grass.

Texas millet (*Panicum texanum*).—In the river bottom lands, especially in the extreme Southwest, this is valued highly for a late hay crop. It is an annual, growing from 2 to 4 feet high, very leafy, and better for hay than for grazing. It prefers rich alluvial soils, where it "comes in" as does the crab grass; on dry uplands its yield is not large. Like crab grass, it should be cut early, before the seeds have matured, when it makes excellent hay, but if left until fully ripe the stems become too hard and woody, and a large part of the seeds drop and are lost. It has not succeeded well in the Atlantic States nor in the northern parts of the Gulf States, but seems specially adapted for use on the river bottom lands of the Southwest. Seed may be sown at any time during the early summer at the rate of 40 pounds per acre, and when one crop has been grown the land will not need reseeding. (Fig. 11.)

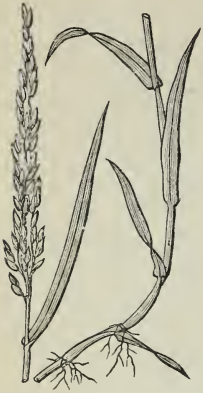
FIG. 11.—Texas millet.

Large water grass (*Paspalum dilatatum*).—This is a native species which has received far less attention than it deserves, though it is found in all parts of the South, growing most abundantly on low, black soils where there is an abundance of moisture. It is a perennial, and spreads slowly from the roots, but it seeds freely, and when once started will soon cover a field where the soil is suited to its growth. It grows from 2 to 5 feet high, and the stems are rather coarse for hay unless cut early; but it produces an immense amount of long broad leaves, which remain fresh and green during the entire winter excepting after unusually heavy frosts. It endures the longest droughts without injury, bears grazing well, starts into growth early in the spring, and is one of our best pasture grasses. Its habit of growing in clumps is against its use for hay, but it is an excellent variety for mixing with redtop for permanent pastures, as it grows best on the same character of soil and largely increases the yield. Seed is rarely found in the market, but a supply can be gathered with little trouble; it may be sown as soon as gathered or early in the spring.

Carpet grass (*Paspalum platycaule*).—On the sandy soils of the South Atlantic and Gulf States this is the most desirable of all grasses for pastures, though its growth is too flat and spreading to make it of value for hay. It is a perennial and, as its name indicates, has a creeping habit of growth which covers the ground rapidly and thoroughly. It is not injured by either frost or drought, and will bear more hard trampling and close grazing than any other grass which has been planted in these tests. It is seldom found on the unsettled lands which have not been trampled, but whenever a field is pastured closely it soon "comes in" and gives good grazing during the entire year. It prefers a sandy soil to one which is heavy, and will grow well even where the sand is quite loose, provided it be

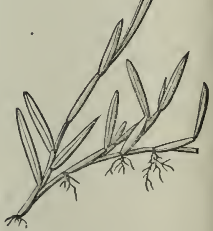
FIG. 12.—Carpet grass.

well trampled, as the trampling seeming to be essential to its successful growth on any soil. It starts well from the seed, and when once established grows rapidly, a single plant often covering from 10 to 20 square feet in the season. It roots at every joint like Bermuda grass, but unlike that plant it is not injured by frosts and is readily destroyed by cultivation. It can be introduced into new fields as directed for Bermuda grass, or if it is mowed late in the season, after the seed has matured and the hay is scattered over the new field, it will soon make good pasturage. (Fig. 12.)

Timothy (*Phleum pratense*).—Although this has been planted repeatedly, not only on the grounds of the stations, but in other places as well, it has rarely given satisfactory returns, and usually disappears during the second or third year from seeding. It has done better at the North Carolina Experiment Station than elsewhere.

Kentucky blue grass (*Poa pratensis*).—This has not given the uniform success here which it has farther north, though in many places, especially in North Carolina, northern Georgia, and on the lime soils of northern Mississippi, it is of considerable value. On low ground, where the soil is dark-colored and contains an abundance of lime, and on "seepy" hillsides, we have seen a few pastures of this grass which afforded good grazing in the late fall and winter months, but it is useless to sow it on the dry clay hills or in the sandy pine woods region. Here it remains almost dormant during the hot weather and its chief value is for mixing with Bermuda grass, lespedeza, and other summer-growing species. Seed should be sown in September, at the rate of 40 pounds per acre. It shows but little during the first year from seeding, but if the soil is suitable it continues to improve for many years. (Fig. 13.)

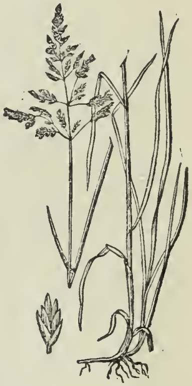

Fig. 13.—Kentucky blue grass.

German millet (*Setaria italica*).—When a crop of hay is wanted from land which has been occupied by oats or any other early crop, German millet can often be used to advantage. It is a grass which requires rich land and which is very exhausting to the soil; it should not be put on land which is to be used next for cotton or grain, though it may often be used to precede clover or the seeding of the field for a permanent pasture. If cut early before the seeds begin to harden it makes excellent hay, but if the seeds are allowed to mature the stems become so hard and woody that they are not eaten well, and the seeds, if fed in any considerable quantity, are often injurious to horses and mules, though not so to cattle. The crop sometimes fails on account of a drought soon after sowing, but if rains follow so as to germinate the seed and give the plants a fair start, they suffer but little from later droughts. There are several varieties, differing principally in size, the form known as "German millet" being the largest, growing from 3 to

5 feet high and making the best yield on heavy soils; the "common millet," growing from 2½ to 4 feet high, and being the best variety for light soils; and the "Hungarian millet," which is the smallest and most quickly maturing sort of the three. Seed may be sown at almost any time during the summer, even as late as the first of August, at the rate of from 25 to 30 pounds per acre.

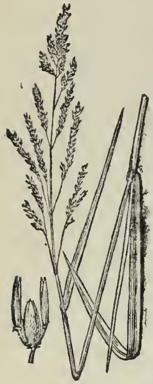
FIG. 14.—Johnson grass.

Johnson grass (*Sorghum halepense*).—This is at the same time one of the most valuable grasses and one of the most troublesome weeds to be found in the South. It is a perennial, which is easily propagated by either seeds or roots, and which makes its best growth on rich bottom lands, where it soon occupies the whole ground, giving three cuttings of about 2 tons each when in good condition. The planter who wishes to grow hay and nothing else, and who has no regard for the rights of his neighbors, will find this a valuable species. We have never seen it permanently cleared from a field where it had once become thoroughly established. (Fig. 14.)

LEGUMINOUS PLANTS.

While the true grasses will always furnish the bulk of the hay crop and the greater part of the pastures, the cultivation of the clovers, melilotus, cowpeas, and other leguminous plants is an essential part of all successful farming, on account of the marked effect which they have in fertilizing and preparing the soil for future crops. The parts of the plants which are above the soil are valuable as food for stock, and those parts which are below the surface of the ground are often of equal value as food for future crops. This is especially true in the Southern States, where the subsoil is often very compact and impervious to water, and where the long-continued heat hastens nitrification and causes the rapid destruction and waste of vegetable matter in the soil. As all of the legumes are deep-rooting plants, they aid greatly in loosening the subsoil, and in consequence cause it to suffer less from excessive rains or from drought; they furnish a large amount of humus, and with a proper rotation of crops will furnish all the nitrogen, the most expensive element in fertilizers, that will be needed for other crops. Soils may be rested and greatly improved by the growing of true grasses, but the same effects can be secured more rapidly, economically, and profitably with leguminous crops, which at the same time will furnish better grazing and hay for all fattening and milch animals.

There are but few of the legumes which will make permanent pastures or meadows, and for such fields the true grasses must be the main dependence, but in most cases the planter will find it more profitable to follow a rotation which will keep his land in forage crops only so long as may be necessary to prepare it for other crops, and for this two years is usually sufficient. While leguminous crops are restorative in the highest degree for a few years, their long continued cultivation on the same ground finally renders the soil incapable of reproducing them profitably. A rotation of crops is universally recognized as being an essential to the highest success in farming, and this rule applies to forage corps as well as to those cultivated with the plow and hoe. In the Southern States the planter has his choice among a large number of these restorative crops, which vary from three months to as many years in completing their growth, and some one of which will be found suited to almost every circumstance in which such a crop may be wanted.

In experiments conducted under the writer's supervision the following species were found to be the most valuable of the leguminous plants:

Cowpea (*Dolichos sinensis*).—There is no other crop which is planted so extensively in the South, both for its hay and its fertilizing value, and we have found no other plant which will produce as large an amount of forage and valuable fertilizing material in as short a time. It may be sown at almost any time during the summer, will grow on any soil except the most barren, and makes excellent hay and pasture. Its long deep roots bring a large amount of plant food from the subsoil and leave it near the surface, where it is available for future crops. There are many varieties of the plant, which are quite different in their habit of growth. Some, like the Unknown and the Clay, produce an immense growth of vine, and require a long season, while others, like the "Pea of the Backwoods," are quite dwarf and mature in two months from planting. Seed of most varieties must be sown every year, though of some, like the Red Tory, the seed may be plowed under in the fall, and the land sown in oats, when another crop will be produced after the oats are harvested. When sown broadcast after wheat, oats, or other early crop, the running sorts make a heavy yield of hay, which, although somewhat difficult to cure, is of the very best quality. Hay of this kind is used almost exclusively to furnish forage for mules on the sugar plantations of Louisiana. By growing such a crop hay is made at a very small expense, and the soil is shaded during the driest and hottest months, and left loose and mellow and in the best possible condition for any future crop.

It is often desirable to plow under some green crop when it is impossible to give up the land for the two years necessary to grow a crop of red clover or melilotus, and in such cases we have no other plant which can take the place of cowpeas. Many planters use the dwarf varieties for planting between the rows of corn or cotton at the last plowing, as when grown in this way they do not interfere with the growing crop and will give a fair yield of seed. The decaying vines make a most excellent covering for the soil during the winter, or they may be used for late pasture. The roots penetrate the soil as deeply as those of red clover, a fact which makes the crop especially valuable for heavy soils requiring drainage. There is no other crop which will furnish the same amount of material for plowing under at so small a cost. When land is not in use for other crops for even two months during the summer it will always pay well to seed it with peas, as the seed or forage which can be gathered will fully pay the cost of seeding and leave the fertilizing value of the crop as clear profit. Seed may be sown at any time from May to August, the amount per acre depending upon the variety and time of sowing. If one of the large varieties is planted in hills early in the season two quarts will plant an acre, but if dwarf varieties are sown broadcast in August not less than a bushel should be used.

Lespedeza, or Japan clover (*Lespedeza striata*).—This plant, which came to this country from Japan, was first noticed in South Carolina, but has now become naturalized as far west as Texas and north to the Ohio River. It is an annual which perpetuates itself without care, and will make a fair growth on the poorest and driest clay hills. It starts rather late in the spring, making little show before June; but from that time on it grows rapidly, and is eaten greedily by all kinds of stock until killed by frost. On sterile soils its growth is flat and spreading, and it is fit only for pasture; but where the soil is of good quality it will grow from 20 to 30 inches high and yield 2 tons per acre of hay which is fully equal in value to the best clover, and is the most profitable hay which can be grown on thin soils for feeding to milch cows and fattening animals. This is not only one of the best hay and pasture plants, but it is also one of the best for fertilizing purposes, as it sends its roots deep into the ground, and will grow on soils too barren for the growth of other legumes. Like most other plants belonging to the same family, it does best on a lime soil, but it will do well on the red clay hills where red clover and melilotus fail. It has not succeeded well on the sandy soils of the pine woods region. Seed should be sown at the rate of a half bushel per acre, with oats in the fall, or by itself early in the spring.

Alfalfa (*Medicago sativa*).—This plant makes such heavy yields in favorable locations that it has received special attention at the experiment stations, but has given widely varying results. On moderately rich and sandy soils it has proved quite valuable for soiling purposes, furnishing cuttings as early as February, with frequent successions until late in the summer, while on dry hills or heavy clay, and on soils where there is a lack of drainage its growth has been weak and unsatisfactory. It has made a better growth on the alluvial soil of the Louisiana Station than any other hay and pasture plant which has been tested, and is the only plant yet found which will successfully occupy the ground throughout the entire year. At that station the first sowing was made in October, 1890; and in June, 1892, twenty months after planting, fourteen cuttings, averaging nearly 1¼ tons per acre, had been taken from the land. Another field sowed in March, 1892, had given two cuttings by the end of June. At the Mississippi Station a field was sown in 1889 which gave three cutting of about $1\frac{1}{2}$ tons each in 1890, while in 1892 the yield had decreased to three cuttings of about 1 ton each. In Florida it has succeeded well when a stand has been secured, while in Georgia and North Carolina it has been less promising. It is difficult to secure a full stand, as the young plants are easily killed by either excessive rains or a hot sun, and we have found September and October the most favorable months for sowing the seed. Sow at the rate of from 20 to 25 pounds per acre.

Bur clover (*Medicago maculata*).—This is an annual plant which makes good winter grazing on rich soils, but which is worthless for summer use and of little value for hay. It is essentially a winter grower, being at its best from February to May, after which it ripens its seed and soon disappears. Horses do not eat it well when other clovers or grasses are abundant, but cattle seem quite fond of it and hogs eat it greedily. We have found it an excellent plant for sowing on Bermuda grass land, as it matures its seed and dies at about the time the Bermuda grass starts into growth, and when the latter is killed by frosts this soon takes its place. A mixture of these two plants comes nearer giving continuous grazing than any other mixture we have tested. For its best growth this clover should have a light and rich soil, and in such a soil will reseed the ground freely, even though the field be plowed for a summer crop. Sow in August at the rate of 15 pounds per acre.

Melilotus (*Melilotus alba*).—This plant bears a close resemblance to alfalfa, but is larger and coarser in every way and is especially adapted for use on calcareous soils. It will make an excellent growth on any lime lands, even on the "rotten limestone" hills and on soils so barren that they will sustain no other plants, but it is of almost no value on the red clays and the sandy pine woods soils, which contain little lime. It is a biennial plant, making only a moderate growth the first season, but during the second season it will grow from 4 to 7 feet in height if not cut, and make stronger and heavier roots than any other forage crop. At the end of the second season it matures its seed and dies, and the roots then decay quickly. It is not generally liked by animals unaccustomed to it, but as it starts into growth very early in the spring when other green forage is scarce, stock turned on it at that time soon acquire a taste for it and eat it readily throughout the remainder of the season. When grown for hay one and sometimes two crops can be cut in the fall after sowing in the spring, and during the next season two or three crops may be cut. Unless cut early the stems become hard and woody, and in all cases care is necessary in handling in order to prevent the loss of

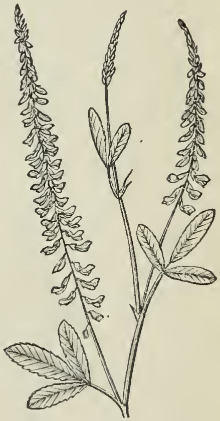
FIG. 15.—Melilotus alba.

leaves which readily drop from the stems. Excellent hay may be made by sowing it on lands which have been set in Johnson grass, the mixture seeming to improve the palatability of both. From land cultivated in this manner we have seen three cuttings of about 2 tons each made in a season. As a restorative crop for yellow loam and white lime lands this plant has no superior, and for black prairie soils it has no equal. The roots are very long, penetrating the soil to a depth of 3 or 4 feet, are quite large, and by their decay at the end of the second year leave the soil with innumerable minute holes, which act as drains to carry off the surplus water and loosen the soil so that the roots of other crops can go deeper, find more abundant supplies of food, and bear drought better. While the hay from this plant will not sell as well as that from lespedeza, the crop is heavier, furnishes pasture earlier in the spring, and is by far the most valuable crop we have for a natural fertilizer. Seed should be sown in August or February at the rate of half a bushel per acre. (Fig. 15.)

Alsike clover (*Trifolium hybridum*).—This, too, varies greatly with the soil on which it is grown, succeeding best on rather low and rich soils, and doing well on soils which are too wet and heavy for the growth of any other clovers. It is a perennial, similar to the white clover in its persistency and general habit, but having nearly the size and vigor of the red clover, which makes it one of the best of pasture plants on suitable soils. Its yield of hay is light, but it bears grazing well, grows thriftily, and bears heavy frosts without injury. It has grown well on heavy and "seepy" clay soils, but has been of little value in dry upland fields as drought injures it seriously and it soon disappears from fields where it does not have an abundant supply of moisture. It is the best of the clovers for mixing with redtop, as it requires the same character of soil and remains in good condition long after the grass has ceased growing. Sow in August or February at the rate of 10 pounds per acre.

Crimson clover (*Trifolium incarnatum*) (also known as scarlet clover).—This clover has attracted great attention in the South during the last three or four years, but the position which it will finally hold is still uncertain. It has succeeded better and seemed to be more at home on the Atlantic coast than elsewhere, and has given better results at the North Carolina Experiment Station than in either Georgia or Mississippi. It has also done well in Louisiana, and in speaking of its growth there Prof. Stubbs says: "It is thoroughly at home in every part of the State, making a large crop of excellent hay. A combination of this crop and cowpeas affords the readiest means of quickly restoring worn-out lands or of furnishing a continual supply of fresh hay for stock." It is an annual which commences its growth with the autumn rains, often affording good pasturage from November to April, when it matures its seed and dies. On favorable soils it reseeds the ground freely and so will produce successive crops from a single seeding, even though the ground be plowed and used for short summer crops like oats or millet. Hay made from it is of good quality, and a yield of 2 tons per acre is not uncommon, though as it matures during cool weather the hay is somewhat difficult to cure. It makes excellent grazing during the fall months after most other feed becomes dry and scarce. Its principal value, however, is as a green crop to be plowed under, as it can be sown in the fall for plowing under in the spring, while the cowpea, melilotus, and most other green manuring crops are summer growers and should be plowed under in the fall. It varies greatly with the soil where it is grown, appearing to be most successful on rather heavy clays containing but little lime, and it has made only a weak and unsatisfactory growth when planted on the light sandy soils of the Gulf coast, although it made one heavy crop, followed by two failures, at the Florida Station. At the North Carolina Station it is valued highly, and good crops have been secured by sowing the seed broadcast in September and October without any previous preparation of the ground, though on other places only a few miles distant, where the ground dries and crusts very quickly, thorough preparation of the land and earlier sowing have been found necessary. Sow from 10 to 15 pounds of seed per acre. (Fig. 16.)

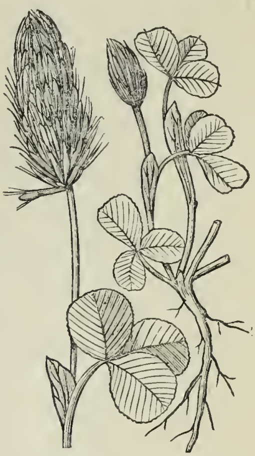
Fig. 16.—Crimson clover.

Red clover (*Trifolium pratense*).—Until recently it has been thought that red clover could not be grown in the Southern States, but our experience has been that on suitable soils and with proper management it will grow fully as well here as in any of the Northern States, and that, while it does not last as long here, its yield is heavier, and on account of its more rapid growth, the quality of hay is better. In North Carolina it has succeeded well and has maintained a full stand longer than in most other sections; while on the sandy white soil of the Florida Station it has done but little. At the Louisiana Station it has made a vigorous growth, affording two large cuttings during the first season, but it soon succumbs to the encroachments of native grasses. At the Mississippi Station on rich creek bottom and on black prairie soils it has given excellent results, making 2 tons of hay per acre in May, another ton in June, and in favorable seasons another ton in September, though the last cutting has been unreliable on account of summer droughts. Where such yields can be made it is one of the best crops which can be grown, but there are many localities in the South where it has not been found profitable. It requires a soil which is rich and in fairly good condition to secure a "catch" of the seed, and on many soils where it makes a promising start and yields two or three cuttings it soon becomes overrun with the native grasses and is choked out. Ordinarily it will not pay to grow it more than two years on the same ground, as by the end of that time it will have done its best work in fertilizing the soil, and the land will give better returns if the last crop of clover is plowed under and the field planted to some other crop. As the plants produce seed abundantly here and are not infested with the insects which have recently caused so much damage to the crop in the Northern States, there seems to be no reason why the seed crop should not become of considerable importance.

Red clover is a universally recognized standard in estimating the values of all other crops, when grown either for hay or as a green manure, and we have made special efforts to test it on as great a variety of soils as possible, and do not hesitate to recommend it for all rich soils which are in good mechanical condition; but it is useless to sow it on barren fields, or on rough and poorly prepared lands of any kind. It seems best suited for growth on alluvial and black prairie soils, and has never been satisfactory on sandy or white lime lands. August sowings have given the best satisfaction, as the plants from such sowings are sufficiently strong to keep down any growth of wild grasses and weeds the next spring, and will give a heavy cutting of hay in May. If sown in February, the more common time, the first cutting will be principally of volunteer grasses, but the clover will give two good cuttings later. Sowing with oats in February is often successful, but the clover is often injured by cutting the oats, thus removing the shade just at the beginning of the hot weather. Sow 1 bushel of the seed to each 5 acres.

Hairy vetch (*Vicia villosa*).—Of the 28 vetches which the Department has tested this is by far the best. Seed of this species was first sown in October, 1888, and since that time it has given heavy annual crops on the same ground, although it has received no attention and the ground has not been plowed since the first sowing. In 1889 another field was sown and has given equally good results. It is an annual plant, similar in growth to a very slender and straggling pea vine, the vines often reaching 10 or 12 feet in length and covering the ground with a dense mat of forage 2 feet in depth. Its seeds germinate with the first autumn rains and in a favorable season cover the ground by the first of January and then furnish good grazing until April or May. If stock are taken off the field in March the plants will mature and reseed the ground freely for the next year, but if pastured until June the stand will be destroyed. Stock of all kinds eat it greedily, both in the pastures and when cut for hay. It bears our heaviest frosts without injury and it is one of the few plants which can be grown during the winter for green manuring. (Fig. 17.)

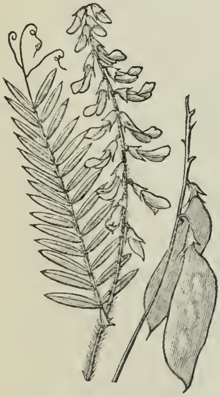

FIG. 17—Hairy vetch.

There is another vetch (*Vicia sativa*), the one commonly known simply as "vetch," which is quite largely grown in some sections of the South, but it is smaller in its growth, less hardy, and in every way inferior to the hairy vetch. The two are easily distinguished, as the hairy vetch has a dark-green hairy leaf and large clusters of purple flowers, while the common vetch has a light-green smooth leaf and small clusters of pink flowers.

We regard the hairy vetch as being the most valuable winter forage plant which the Department has imported, and unhesitatingly recommend it for cultivation on all rich soils. Sow in August or September, at the rate of 2 bushels per acre.

MEXICAN CLOVER (*Richardsonia scabra*).

This is not a true clover, but takes its name from its habit of growth, which is similar to that of red clover. It is an annual, a native of Mexico and Central America, and has become thoroughly naturalized in all the southern part of the pine-woods region. A sandy soil seems essential to its growth and, like the crab grass, it is much more abundant in cultivated fields than elsewhere, coming up after other crops are harvested and making its best growth late in the season. It is of little value for pasture, but when cut for hay the yield is often 2 tons or more per acre. The hay, which is usually mixed with more or less crab grass, is of excellent quality. While its roots do not go as deep as those of the true clovers, it makes such a rank growth that it is of considerable value as a fertilizer and for covering the ground through the winter.

SUMMARY.

With reference to the selection of forage plants adapted to different regions, the soils of the South Atlantic and Gulf States may be classified as follows:

(1) Yellow loam soils, (2) alluvial and river bottom soils, (3) black prairie soils, (4) pine woods soils.

The forage plants most successfully grown for different purposes on these soils are enumerated below:

Forage plants for yellow loam soils.—For permanent meadows on rich land, Bermuda grass; for a hay crop to occupy rich land two years, red clover; for a single hay crop on fair soils, cowpeas; on poor soil, lespedeza. For permanent pastures Bermuda grass and lespedeza, to which may be added on dry soils orchard grass, Hungarian brome grass, and bur clover; on wet soils the addition should consist of redtop, water grass, and alsike clover. Crimson clover, rescue grass, Terrell grass, and hairy vetch are recommended for winter pasture.

Forage plants for the alluvial and river bottom soils.—For permanent meadows, Bermuda grass and red clover; on wet spots, redtop; and on well-drained soils, alfalfa. For a hay crop for a single season, lespedeza or German millet. For pastures, Bermuda grass, lespedeza, redtop, alsike clover, bur clover, alfalfa, Japanese rye grass, large water grass, and Terrell grass.

Forage plants for the black prairie soils.—For hay, Bermuda grass, red clover, and melilotus. For a hay crop for a single season, lespedeza. For a catch crop, following oats, potatoes, etc., cowpeas or German millet. For pastures, Bermuda grass, lespedeza, melilotus, alsike clover, Hungarian brome grass, orchard grass, redtop, bur clover, and hairy vetch.

Forage plants for the pine woods soils.—For hay, Bermuda grass, crab grass, Mexican clover, alfalfa, crimson clover, and lespedeza. For pastures, crimson clover, Japanese rye grass, orchard grass, carpet grass, and large water grass.

It must be remembered that variations in local conditions of soil and climate make it necessary to exercise great care in the selection of forage plants for particular purposes. The more complete statements of the conditions under which different species have proved successful, given in the body of this bulletin, should be considered in detail before definite conclusions are drawn regarding the value of particular plants for any locality.

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 19.

IMPORTANT INSECTICIDES:

DIRECTIONS FOR THEIR PREPARATION AND USE.

[REVISED EDITION.]

BY

C. L. MARLATT,
FIRST ASSISTANT ENTOMOLOGIST.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Entomology,
Washington, D. C., January 17, 1895.

Sir: I have the honor to transmit herewith a revised edition of Farmers' Bulletin No. 19, a condensed account of the more important insecticides for farm and garden use, prepared under my direction by Mr. C. L. Marlatt, first assistant entomologist. As stated in my letter of transmittal to the first edition, circular No. 1, new series, of this division, contained information of this character, but this document is out of print, and since it was published some advance has been made in the matter of insecticides which necessitates the publication of some additional matter and some change in the methods of preparation of old and standard mixtures. The constant call for information of this character will warrant the publication of this bulletin in large edition.

Respectfully,

L. O. Howard, *Entomologist.*

Hon. Chas. W. Dabney, Jr.,
Acting Secretary of Agriculture.

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IMPORTANT INSECTICIDES: DIRECTIONS FOR THEIR PREPARATION AND USE.

Without going minutely into the field of remedies and preventives for insect depredators, it is proposed to give in this bulletin brief directions concerning a few of the insecticide agents having the widest range and attended with the greatest usefulness, economy, and ease of application. These are not covered by patent, and in general it is true that the patented articles are inferior, and many of the better of them are in fact merely more or less close imitations of the standard substances and compounds hereinafter described. Only such brief references to food and other habits of the insects covered will be included as are necessary to illustrate the principles underlying the use of the several insecticide agents recommended.

Relation of Food Habits to Remedies.

For the intelligent and practical employment of insecticides it is necessary to comprehend the nature and method of injury commonly due to insects. Omitting for the present purpose the many special cases of injury which necessitate peculiar methods of treatment, the great mass of the harm to growing plants from the attacks of insects falls under two principal heads based on distinct principles of food economy of insects, viz, whether they are biting (mandibulate) or sucking (haustellate), each group involving a special system of treatment.

INJURY FROM BITING INSECTS.

The biting or gnawing insects are those which actually masticate and swallow some portion of the solid substance of the plant, as the wood, bark, leaves, flowers or fruit. They include the majority of the injurious larvæ, many beetles, and the locusts.

For these insects direct poisons, such as the arsenicals, which may be safely applied to the leaves or other parts of the plant attacked, and which will be swallowed by the insect with its food, furnish the surest and simplest remedy, and should always be employed except where the parts treated are themselves to be shortly used for the food of other animals or of man.

INJURY FROM SUCKING INSECTS.

The sucking insects are those which injure plants by the gradual extraction of the juices, either from the bark, leaves, or fruit, and include the plant-bugs, plant-lice, scale insects, thrips, and plant-feeding mites. These insects possess, instead of biting jaws, sucking beaks or bristles, which are thrust down through the outer layers of the bark or leaves into the soft, succulent tissues beneath and used to extract the plant juices, with a resulting injury not so noticeable as in the first group, but not less serious.

For this class of insects the application of poisons, which penetrate little, if at all, into the plant cells, is of trifling value, and it is necessary to use substances which will act externally on the bodies of these insects, either as a caustic or to smother or stifle them by closing their breathing pores, or to fill the air about them with poisonous fumes. Of value also as repellants are various deterrent or obnoxious substances.

Wherever it is not desirable to use poisons for biting insects, some of the means just enumerated will often be available.

GROUPS SUBJECT TO SPECIAL TREATMENT.

The general grouping outlined above relates to the species which live and feed upon the exterior of plants for some portions or all of their lives, and includes the great majority of the injurious species. Certain insects, however, owing to peculiarities of habit, inaccessibility, or other causes, require special methods of treatment. Of these, two groups properly come within the scope of this bulletin: (1) Those working beneath the soil, or subterranean insects, such as the white grubs, root-maggots, root-lice, etc., and (2) insects affecting stored products, as various grain and flour pests.

Three other groups, which include species requiring very diverse methods of treatment, and therefore not coming within the limits of this bulletin, are (1) the internal feeders, such as wood, bark, and stem borers, leaf-miners, gall insects, and species living within fruits; (2) household pests, and (3) animal parasites.

The classification of insects outlined above, based on mode of nourishment and indicating groups amenable to similar remedial treatment, simply stated, is as follows:

I. External feeders:
    (*a*) Biting insects.
    (*b*) Sucking insects.
II. Internal feeders.
III. Subterranean insects.
IV. Insects affecting stored products.
V. Household pests.
VI. Animal parasites.

INSECTICIDES FOR EXTERNAL BITING INSECTS (FOOD POISONS).

THE ARSENICALS: PARIS GREEN AND LONDON PURPLE.

The arsenical compounds have supplanted all other substances for the insects falling under this heading. Two compounds are in common use, viz, Paris green and London purple.[1] The use of powdered white arsenic is not recommended, on account of its greater liability to scald foliage and because it is very apt to be mistaken for harmless substances. Of the first two mentioned, Paris green is the stronger insecticide, acting quickly, and is less liable to burn foliage. London purple has the advantage of cheapness, and, being more finely powdered, is kept more easily suspended in water. The former can be had in 14-pound or larger cans at 20 cents per pound, and the latter at 10 cents per pound by the barrel.

HOW TO APPLY ARSENICALS.

There are three principal methods of applying arsenicals. The wet method, which consists in using these poisons in water in the form of spray, is the standard means, secures uniform results at least expense, and is the only practical method of protecting fruit and shade trees. The dry application of these poisons in the form of a powder, which is dusted over plants, is more popular as a means against the cotton worm in the South, where the rapidity of treatment possible by this method, and its cheapness, give it a value against this insect, in the practical treatment of which prompt and economical action are the essentials. This method is also feasible for any low-growing crop, such as the potato. The third method consists in the use of the arsenicals in the form of poisoned baits, and is particularly available for such insects as cutworms, wireworms, and local invasions of locusts.

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[1] A third arsenical which promises well, arsenate of lead, has lately been experimented with by the Gypsy Moth Commission. While not urging that this insecticide has advantages over Paris green, it is held that it has the merit of showing on the leaves, indicating at once which have been sprayed, remains much more easily suspended in water, and may be used in large proportions without danger to foliage. It has recently been extensively tested at the Department, and a strength as great as 1 pound to 2 gallons of water has been used on tender foliage of the peach and Osage orange without injury. Good results have attended its use also against the imported elm leaf-beetle. The insecticide results were not better, however, than with Paris green; but for such sensitive foliage as that of the peach, or where no risk of scalding may be taken, I am inclined to believe that it will prove useful.

This insecticide is prepared by combining, approximately, 3 parts of arsenate of soda with 7 parts of acetate of lead. These substances unite chemically and form a fine, white powder which remains easily in suspension. As now used by the Commission, 10 pounds of the arsenate of lead are used with 150 gallons of water, 2 quarts of glucose being added to cause the insecticide to adhere longer to the leaves. Professor Fernald's experience and our own would indicate that from one-fourth to one-half this strength will answer for most larvæ—the larvæ of the gypsy moth proving to be unusually resistant to the action of poisons. The arsenate of lead costs the commission 7 cents a pound wholesale, and glucose $16 a barrel.

The wet method.—Either Paris green or London purple may be used at the rate of 1 pound to 100 to 250 gallons of water, or 1 ounce to 6 to 15 gallons. The stronger mixtures are for such vigorous foliage as that of the potato, for the Colorado potato-beetle, and the greater dilutions for the more tender foliage of the peach or plum. An average of 1 pound to 150 gallons of water is a good strength for general purposes. The poison should be first made into a thin paste in a small quantity of water and powdered or quick lime added in amount equal to the poison used to take up the free arsenic and remove or lessen the danger of scalding. An excess of lime will do no injury. The poisons thus mixed should be strained into the spray tank or reservoir, care being taken that all the poison is pulverized and washed through the meshes of the strainer. The use of the lime is especially desirable in the case of the peach and plum, the foliage of which, particularly the former, is very tender and easily scalded. To the stronger foliage of the apple and most shade trees Paris green may be applied at the strength of 1 pound to 150 gallons of water without danger; with London purple it is always better to use the lime.

If it be desirable to apply a fungicide at the same time, as on the apple for the codling moth and the apple scab fungus, the Bordeaux mixture[1] may be used instead of water, adding the arsenical to it at the same rate per gallon as when water is used. The lime in this fungicide neutralizes any excess of free arsenic and makes it an excellent medium for the arsenical, removing, as it does, all liability of scalding the foliage and enabling an application of the arsenical, if necessary, eight or ten times as strong as it could be employed with water alone.

The arsenicals can not be safely used with most other fungicides, such as the sulphate of copper, eau celeste or iron chloride solution, the scalding effects of these in the mixture being greatly intensified.

The dry method.—The following description applies to the pole-and-bag duster commonly used against the cotton worm: A pole 5 to 8 feet long and about 2 inches in diameter is taken, and a three-fourths inch hole bored through it within 6 inches of either end. Near each end is securely tacked a bag of "8-ounce osnaburg cloth," 1 foot wide and 18 inches to 2 feet long, so that the powdered poison may be introduced into the bags with a funnel through the holes at the ends of the pole. The bags are filled with undiluted Paris green, which is generally preferred to London purple on account of its quicker action, and the apparatus is carried, on horse or mule back, through the cotton fields, dusting two or four rows at once. The shaking induced by the motion of the animal going at a brisk walk or at a trot is sufficient to dust the plants thoroughly, or the pole may be jarred by hand. The application is preferably made in early morning or late evening when the dew is on, to cause the poison to adhere better to the foliage.

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[1] *Bordeaux mixture formula.*—Into a 50-gallon barrel pour 30 gallons of water, and suspend in it 6 pounds of bluestone in coarse sacking. Slack 4 pounds of fresh lime in another vessel, adding water slowly to obtain a creamy liquid, free from grit. When the bluestone is dissolved add the lime milk slowly with water enough to fill the barrel, stirring constantly.

With insufficient lime the mixture sometimes injures the foliage, and it should be tested with a solution obtained by dissolving an ounce of yellow prussiate of potash (potassium ferrocyanide) in one-half pint of water. If there be insufficient lime in the Bordeaux mixture the addition of a drop or two of this solution will cause a brownish-red color, and more lime should be added until no change takes place when the solution is dropped in. Use the Bordeaux mixture promptly, as it deteriorates on standing.

Stock solutions of both the bluestone and lime may be kept for any length of time. Make the stock bluestone by dissolving in water at the rate of 2 pounds to the gallon. The stock lime is slacked and kept as a thick paste. Cover both mixtures to prevent evaporation and keep the lime moist. For the 50-gallon formula add 3 gallons of the bluestone solution to 50 gallons of water, and introduce the stock lime slowly until there is no reaction with the testing solution.—B. T. G.

From 1 to 2 pounds are required to the acre, and from 10 to 20 acres are covered in a day. The occurrence of heavy rains may necessitate a second application, but frequently one will suffice. This simple apparatus, on account of its effectiveness and cheapness, is employed throughout the cotton belt to the general exclusion of more complicated and expensive machinery.

With the patented air-blast machines for the dry distribution of poisons, arsenicals are diluted with 10 parts of flour, lime, or ground gypsum, and from 60 to 75 acres may be covered in a day by using relays of men and teams. Greater uniformity is secured with these machines in distribution of the poisons, but their cost (from $30 to $60) prevents their general use.

The planter should have a good supply of poison on hand and apparatus for its application prepared in advance, since when the worm puts in an appearance its progress is very rapid, and a delay of a single day may result in material damage to the crop.

If small garden patches are dusted with poison by this or similar means from bags or with hand powder bellows, it is advisable always to dilute the poison with 10 parts of flour, or preferably lime, and for application to vegetables which may soon be used for food, as the cabbage, 1 ounce of the poison should be mixed with 6 pounds of flour or 10 of lime, and dusted merely enough to show evenly over the surface.

As poisoned bait.—It is not always advisable or effective to apply arsenicals directly to the plants, and this is particularly true in the case of the attacks of the grasshopper and of the various cutworms and wireworms. In such cases the use of poisoned bait has proven very satisfactory.

For locusts, take 1 part by weight of white arsenic, 1 of sugar, and 6 of bran, to which add water to make a wet mash. Place a teaspoonful of this at the base of each tree or vine, or apply a line of baits just ahead of the advancing army of grasshoppers, placing a tablespoonful of the mash every 6 or 8 feet, and following up with another line behind the first.

For baiting cutworms and wireworms, distribute poisoned green, succulent vegetation, such as freshly cut clover, in small bunches about in the infested fields. Dip the bait in a very strong arsenical solution, and protect from drying by covering with boards or stones. Renew the bait as often as it becomes dry, or every three to five days. The bran-arsenic bait will also answer for cutworms.

TIME TO SPRAY FOR BITING INSECTS.

For the codling moth, the apple and pear should receive the first application very soon after the blossoms fall, which is also the time for the second treatment of the scab fungus; the second spraying should be given one or two weeks later, just before the fruit turns down on the stem or when it is from one-fourth to one-half inch in diameter. The first spraying reaches the eggs laid by the moth in the flower end of the fruit shortly after the falling of the blossoms, and the second the later egg-laying by the more belated moths, when the first coating of poison will probably have been washed off by rains. The young larva, eating its way from without into the fruit, gets enough of the poison to destroy it. This treatment reaches at the same time a large number of leaf-feeding enemies of these fruit trees.

For the Curculio of the stone fruits, plum, cherry, peach, etc., two or three applications should be made; the first before the trees bloom or as soon as the foliage is well started, the second at the time of the exposure of the young fruit by the falling of the blossoms, and perhaps a third a week later, particularly if rains have intervened after the last treatment. The poison here acts to destroy the parent Curculio instead of the young larvæ, which, hatching from eggs placed beneath the skin of the fruit, are not affected by the poison on the outside. The adult Curculio, however, as soon as it comes from its hibernation feeds on the foliage before the trees bloom, and later on the young fruit also, and is destroyed by the arsenical before its eggs are deposited.

For leaf-feeding insects in general, such as the Colorado potato-beetle, blister beetles, elm leaf-beetle, maple worm, etc., the application should be made at the earliest indication of injury and repeated as often as necessary. Fruit trees should never be sprayed when in bloom on account of the liability of poisoning honey bees or other insects useful as cross fertilizers.

CARE IN USE OF ARSENICALS.

It must be remembered that these arsenicals are very poisonous, and should be so labeled. If ordinary precautions are taken there is no danger to man or team attending their application, and the wetting of either, which can not always be avoided, is not at all dangerous, on account of the great dilution of the mixture, and no ill results whatever have resulted from this source.

The poison disappears from the plants almost completely within twenty to twenty-five days, and even if the plants were consumed shortly after the application an impossible quantity would have to be eaten to get a poisonous dose. To illustrate, in the case of the apple, if the entire fruit were eaten, core and all, it would take several barrels at a single sitting to make a poisonous dose (Riley), and with the cabbage, dusted as recommended above, 28 heads would have to be eaten at one meal to reach this result (Gillette). It is preferable, however, to use other insecticides in the case of vegetables soon to be eaten, and thus avoid all appearance of danger.

INSECTICIDES FOR EXTERNAL SUCKING INSECTS (CONTACT POISONS).

The simple remedies for this class of insects, such as soap and lye washes, tobacco decoction, etc., are frequently of the greatest service, but need no special explanation. The whale oil is the most valuable of the soaps, and at the rate of 1 pound to 4 gallons of water, dissolved by heating, kills most soft-bodied insects, and at 1 to 2 pounds to the gallon is an effective winter wash for scale insects, even the very resistant San José scale succumbing to the latter strength. The insect powders (Pyrethrum or Buhach) are effective, but too expensive for any but limited or indoor use. The following are standard remedies for this group of insects: Kerosene emulsions, resin washes, hydrocyanic acid gas, and vapor of bisulphide of carbon.

THE KEROSENE WASHES.

The kerosene and soap emulsion formula.

Kerosene	gallons	2
Whale-oil soap (or 1 quart soft soap)	pound	½
Water	gallon	1

The soap, first finely divided, is dissolved in the water by boiling and immediately added boiling hot, away from the fire, to the kerosene. The whole mixture is then agitated violently while hot by being pumped back upon itself with a force pump and direct-discharge nozzle throwing a strong stream, preferably one-eighth inch in diameter. After from three to five minutes' pumping the emulsion should be perfect, and the mixture will have increased from one-third to one-half in bulk and assumed the consistency of cream. Well made, the emulsion will keep indefinitely, and should be diluted only as wanted for use.

The use of whale oil soap, especially if the emulsion is to be kept for any length of time, is strongly recommended, not only because the soap possesses considerable insecticide value itself, but because the emulsion made with it is more permanent, and does not lose its creamy consistency, and is always easily diluted, whereas with most of the other common soaps the mixture becomes cheesy after a few days and needs reheating to mix with water. Soft soap answers very well, and 1 quart of it may be taken in lieu of the hard soaps.

In limestone regions or where the water is very hard some of the soap will combine with the lime or magnesia in the water and more or less of the oil will be freed, especially when the emulsion is diluted. Before using, such water should be broken with lye, or rain water employed; but better than either, follow the milk emulsion formula, with which the character of the water, whether hard or soft, does not affect the result.

The kerosene and milk emulsion formula.

Kerosene	gallons	2
Milk (sour)	gallon	1

Heating is unnecessary in making the milk emulsion, which otherwise is churned, as in the former case. The change from a watery liquid to a thick buttery consistency, much thicker than with the soap, takes place very suddenly after three to five minutes' agitation. With sweet milk difficulty will frequently be experienced, and if the emulsion does not result in five minutes, the addition of a little vinegar will induce prompt action. It is better to prepare the milk emulsion from time to time for immediate use, unless it can be stored in quantity in air-tight jars, otherwise it will ferment and spoil after a week or two.

How to use the emulsions.—During the growing period of summer, for most plant-lice and other soft-bodied insects, dilute the emulsion with from 15 to 20 parts of water; for the red spider and other plant mites the same, with the addition of 1 ounce of powdered sulphur to the gallon; for scale insects, the larger plant bugs, larvæ, and beetles, dilute with from 7 to 9 parts water; apply with spray pump.

For winter applications to the trunks and larger limbs of trees, in the dormant and leafless condition, to destroy scale insects, stronger mixtures may be used even to the pure emulsion, which latter can not be sprayed successfully but may be applied with brush or sponge. Diluted with one or more parts of water it may be applied in spray without difficulty. The use of the pure emulsion is heroic treatment and only advisable in cases of excessive infestation, and in general it is much better and safer to defer the treatment until the young scales hatch in the spring, when the nine-times diluted wash may be used with more certain results and without danger to plants. The winter treatment should be followed by a use of the spring wash to destroy any young which may come from female scales escaping the stronger mixture.

Pure kerosene.—The pure oil may be applied as a winter wash to the older parts of plants either in a spray or with a sponge, using the least possible quantity. Its use is not advised save in exceptionally bad cases of infestation and during the dormant period, and should never be attempted after the first sign of spring growth appears.

In many cases plant-bugs and beetles may be jarred into cloths saturated with kerosene or into pans with water and oil and destroyed, where it would be unsafe or inadvisable to spray the plants themselves.

As a remedy against the mosquito, kerosene has proven very effective

(Howard). It is employed to destroy the larvæ of the mosquitoes in their favorite breeding places in small pools, still ponds, or stagnant water, and where such bodies of water are not sources of drinking supply or of value for their fish, especially in the case of temporary pools from rains, which frequently breed very disagreeable local swarms, the use of oil is strongly recommended. The kerosene is applied at the rate of 1 ounce to 15 square feet of water surface, and forms a uniform film over the surface and destroys all forms of aquatic insect life, including the larvæ of the mosquito and also the adult females coming to the water to deposit their eggs. The application retains its efficiency for several weeks, even with the occurrence of heavy rains.

THE RESIN WASH.

This wash has proved of greatest value in California, particularly against red scale (*Aspidiotus aurantii*), and will be of use in all similar climates where the occurrence of comparatively rainless seasons insures the continuance of the wash on the trees for a considerable period, and where, owing to the warmth, the multiplication of the scale insects continues almost without interruption throughout the year. Where rains are liable to occur at short intervals, and in the Northern States, the quicker-acting and stronger kerosene washes are preferable. The resin wash acts by contact, having a certain caustic effect, but principally by forming an impervious, smothering coating over the scale insects. The application may be more liberal than with the kerosene washes, the object being to thoroughly wet the bark.

The wash may be made as follows:

Resin	pounds	20
Crude caustic soda (78 per cent)	do	5
Fish oil	pints	2½
Water to make	gallons	100

Ordinary commercial resin is used, and the caustic soda is that put up for soap establishments in large 200-pound drums. Smaller quantities may be obtained at soap factories, or the granulated caustic soda (98 per cent) used—3½ pounds of the latter being the equivalent of 5 pounds of the former. Place these substances with the oil in a kettle with water to cover them to a depth of 3 or 4 inches. Boil for one or two hours, making occasional additions of water, or until the compound resembles very strong black coffee. Dilute to one-third the final bulk with hot water, or with cold water added slowly over the fire, making a stock mixture, to be diluted to the full amount as used. When sprayed the mixture should be perfectly fluid, without sediment, and should any appear in the stock mixture reheating should be resorted to.

As a winter wash for scale insects, and particularly for the more resistant San José scale (*Aspidiotus perniciosus*), stronger washes are necessary. In southern California, for this latter insect, the equivalent of a dilution one-third less, or to 66⅔ gallons instead of 100, has given very good satisfaction. In Maryland, with this insect, it has proved necessary to use the wash at 6 times the summer strength to destroy all of the well-protected hibernating scales; and with other scale insects much stronger mixtures than those used in California have, in the east, proved ineffectual. For regions, therefore, with moderately severe winters, the use of the resin wash to destroy hibernating scale insects seems inadvisable.

TIME TO SPRAY FOR SUCKING INSECTS.

For the larger plant bugs and the aphides, or active plant lice, and all other sucking insects which are present on the plants injuriously for comparatively brief periods, or at most during summer only, the treatment should be immediate, and if in the form of spray on the plants, at a strength which will not injure growing vegetation.

For scale insects and some others, as the pear Psylla, which hibernate on the plants, two or more strengths are advised with most of the liquid insecticides recommended, the weaker for summer applications and the more concentrated as winter washes. The summer washes for scale insects are most effective against the young, and treatment should begin with the first appearance of the larvæ of the spring or any of the later broods, and should be followed at intervals of seven days with two or three additional applications. The first brood, for the majority of species in temperate regions, will appear during the first three weeks in May. Examination from time to time with a hand lens will enable one to determine when the young of any brood appear.

The winter washes may be used whenever summer treatment can not be successfully carried out, and are particularly advantageous in the case of deciduous plants with dense foliage which renders a thorough wetting difficult in summer, or with scale insects which are so irregular in the time of disclosing their young that many summer treatments would be necessary to secure anywhere near complete extermination. In the winter also, with deciduous trees, very much less liquid is required, and the spraying may be much more expeditiously and thoroughly done. In the case of badly infested trees, a vigorous pruning is advisable as a preliminary to treatment.

All of the washes mentioned are excellent as summer remedies. As winter washes for temperate regions the kerosene mixtures and whale-oil soap solutions, particularly the latter, have so far given the best results. These stronger mixtures may be applied at any time during the dormant period of vegetation, and, with deciduous trees, preferably immediately after the falling of the foliage. In the growing season any of these stronger washes would cause the loss of foliage and fruit, and the more concentrated probably the death of the plant.

THE GAS TREATMENT.

Hydrocyanic Acid Gas.

The hydrocyanic acid gas treatment of scale-infested trees, until recently exclusively confined to California, has, within the last year, been introduced in the East by the Department to combat the San José scale. Briefly, it consists in inclosing a tree (or nursery stock in greater or less quantities at once) with a tent and filling the latter with the poisonous fumes generated with potassium cyanide and sulphuric acid.

The outfit.—The tents are made of blue or brown drilling or 8-ounce duck, and painted or oiled with linseed oil to make them as near airtight as possible. A very convenient form of tent is made in the shape of a large hexagonal sheet, which, thrown over a tree, will touch the ground on all sides. These sheets or tents are placed over the trees by hand or with poles in case of small trees, but with trees over 10 feet high some sort of a tripod or derrick is used. The outfit for medium-sized trees—tent and derrick—will cost from $15 to $25. A tent for trees 26 feet tall by 60 feet in circumference costs as much as $60.

The chemicals.—Commercial fused potassium cyanide, 58 per cent purity (costing in bulk 40 cents per pound), commercial sulphuric acid (at 3½ cents per pound), and water are used in generating the gas, the proportions being 1 ounce by weight of the cyanide, slightly more than 1 fluid ounce of the acid, and 3 fluid ounces of water to every 150 cubic feet of space inclosed.

The method.—The generator, which may be any glazed earthenware vessel of 1 or 2 gallons' capacity, is placed within the tent under the tree and the water, acid and cyanide, the latter broken up, put in in the order named, after which the operator withdraws from the tent. The tent is allowed to remain on the tree for one-half hour for large trees or fifteen minutes for small ones. The treatment is best made on cloudy days, early in the morning, late in the evening, or at night. Bright, hot sunlight is liable to cause injury to the foliage, which, however, may be largely avoided by using tents of dark material or painted black.

Three or four men can operate six tents at once, and the expense under such conditions, not counting the cost of the outfit, need not be more than 10 cents per tree. One outfit of tents and hoisting apparatus will answer for an entire community or county.

Bisulphide of Carbon Vapor.

In line with the use of hydrocyanic acid gas is the employment of the vapor of bisulphide of carbon to destroy insects on low-growing plants, such as the lice on melon and squash vines. The treatment, as successfully practiced by Professors Garman and Smith, consists in covering the young vines with small tight boxes 12 to 18 inches in diameter, of either wood or paper, and introducing under each box a saucer containing one or two teaspoonfuls (1 or 2 drams) of the very volatile liquid, bisulphide of carbon. The vines of older plants may be wrapped about the hill and gathered in under larger boxes or tubs, and a greater, but proportional, amount of bisulphide used. The covering should be left over the plants for three quarters of an hour to an hour, and with 50 to 100 boxes a field may be treated with comparative rapidity.

DUSTING AND SPRAYING APPARATUS.

For the application of powders the dusting bags already described are very satisfactory, or for garden work some of the small powder bellows and blowers are excellent. The best of these cost about $2 each and are on the market in many styles.

Better apparatus is required for the wet applications where successful results require the breaking up of the liquid into a fine mist-like spray. The essential features of such an apparatus are a force pump, several yards of one-half inch cloth-reinforced hose with bamboo hoisting rod, and a spray tip. The size of the apparatus will depend on the amount of vegetation to be treated. For limited garden work and for the treatment of low plants the knapsack pumps or the small bucket force-pumps are suitable, the former costing about $14 and the latter from $6 to $9.

Ready fitted pumps, knapsack and others, for the application of insecticides, are now made by all the leading pump manufacturers of this country and also large reservoirs with pump attached for extended orchard operations, the price of the latter ranging from $25 to $75.

The cost of a spraying outfit for orchard work may be greatly reduced by combining a suitable pump and fixtures with a home-constructed tank or barrel to be mounted on a cart or wagon. A spray-tank having a capacity of about 150 gallons is a very satisfactory size, and may be conveniently made 4 feet long, by 2½ wide by 2 deep, inside measurements. It should be carefully constructed, so as to be water-tight, and should be strengthened by four iron bolts or rods across the ends, one each at the top and bottom. A good double-acting force-pump may be obtained from any of the leading pump manufacturers at a cost of from $10 to $20, depending upon whether of iron or brass, and the nature of its fittings. For use in a very large orchard or in city parks, it may be advisable to construct the tank of twice the capacity mentioned to expedite the spraying and to avoid the more frequent refillings necessary with the smaller tank.

The more economical spray tips in the amount of liquid required are the different styles of cyclone nozzles, the best form of which is known to the market generally as the Vermorel nozzle. These are manufactured by the leading spray pump companies. Other good nozzles are also on the market. The common garden spraying and hose nozzles are much too coarse for satisfactory work, and are wasteful of the liquid.

A prime essential in spraying, especially where the large reservoirs are employed, is to keep the liquid constantly agitated to prevent the settling of the poison to the bottom of the tank. This may be accomplished by constant stirring with a paddle, by shaking, but preferably by throwing a stream of the liquid back into the tank. Many of the larger pumps are now constructed with two discharge orifices with this latter object in view, and the use of such is recommended.

For fruit trees of average size, or, if apple, such as would produce from 10 to 15 bushels of fruit, from 3 to 7 gallons of spray are necessary to thoroughly wet each tree. For smaller trees, such as plum and cherry, 1 gallon to the tree will be sufficient. If an average of 5 gallons to the tree be taken for an apple orchard of 1,000 trees 5,000 gallons of spray would be required. About 33 pounds of paris green or london purple would be needed for one spraying, if used at the rate of 1 pound to 150 gallons of water, and for the two applications ordinarily recommended, 66 pounds. This, for the paris green, at 20 cents a pound, would amount to $13.20, and the london purple, at 10 cents a pound, to $6.60, or a little over 1 cent a tree for the former and one-half a cent for the latter.

In spraying orchard trees, it will be found convenient in going between the rows to spray on either side, half of each tree in the row at a time and finish on the return, rather than attempt to spray all sides of one tree before taking up another.

The object in spraying is to coat every leaf and part of the plant as lightly as feasible with thoroughness, and to avoid waste in doing this a mist spray is essential. The application to any part should stop when water begins to drip from the leaves. A light rain will not remove the poison, but a dashing one will probably necessitate a renewal of the application.

REMEDIES FOR SUBTERRANEAN INSECTS.

Almost entire dependence is placed on the caustic washes, or those that act externally, for insects living beneath the soil on the roots of plants, including both sucking and biting insects, prominent among which are the white grubs, maggots in roots of cabbage, radishes, onions, etc., cutworms, wireworms, apple and peach root-lice, the grape phylloxera, and many others.

The insecticide must be one that will go into solution and be carried down by water. Of this sort are the kerosene emulsions and resin wash—the former preferable—the potash fertilizers, muriate and kainit, and bisulphide of carbon. Submersion, wherever the practice of irrigation or the natural conditions make it feasible, has also proven of the greatest service against the phylloxera.

Kerosene emulsion and resin wash.—Either the kerosene and soap emulsion or the resin wash, the former diluted 15 times and the latter at the strength of the winter mixture, are used to saturate the soil about the affected plants and either left to be carried down by the action of rains or washed down to greater depths by subsequent waterings.

For the grape phylloxera or the root-louse of the peach or apple, make excavations 2 or 3 feet in diameter and 6 inches deep about the base of the plant, and pour in 5 gallons of the wash. If not a rainy season, a few hours later wash down with 5 gallons of water and repeat with a like amount the day following. It is better, however, to make this treatment in the spring, when the more frequent rains will take the place of the waterings.

For root maggots enough of the wash is put along at the base of the plant to wet the soil to a depth of 1 to 2 inches, preferably following after an hour with a like amount of water.

For white grubs in strawberry beds or in lawns the surface should be wetted with kerosene emulsion to a depth of 2 or 3 inches, following with copious waterings to be repeated for two or three days. The larvæ go to deeper and deeper levels and eventually die.

Potash fertilizers.—For white grubs, wireworms, cutworms, corn root-worms, and like insects, on the authority of Prof. J. B. Smith, either the kainit or muriate of potash, the former better, are broadcasted in fertilizing quantities, preferable before or during a rain so that the material is dissolved and carried into the soil at once. These not only act to destroy the larvæ in the soil, but are deterrents, and truck lands constantly fertilized by these substances are noticeably free from attacks of insects. This, in a measure, results from the increased vigor and greater resistant power of the plant, which, of itself, more than compensates for the cost of the treatment. The value of these fertilizers against the wireworms is, however, questioned by Prof. J. H. Comstock.

For the root-louse of peach and apple work the fertilizer into the general surface of the soil about the trees, or put it in a trench about the tree 2 feet distant from the trunk.

For cabbage and onion maggots apply in little trenches along the roots at the rate of 300 to 500 pounds to the acre, and cover with soil.

These fertilizers (and the nitrate of soda is nearly as good) are also destructive to the various insects which enter the soil for hibernation or to undergo transformation.

Bisulphide of carbon.—This is the great French remedy for the phylloxera, 150,000 acres being now subjected to treatment with it, and applies equally well to all other root-inhabiting lice. The treatment is made at any season except the period of ripening of the fruit, and consists in making holes about the vines 1 foot to 16 inches deep and pouring into each about one-half ounce of bisulphide, and closing the hole with the foot. These injections are made about 1½ feet apart, and not closer to the vines than 1 foot. It is better to make a large number of small doses than a few large ones. Hand injectors and injecting plows are employed in France to put the bisulphide into the soil about the vines, but a short stick or iron bar may be made to take the place of these injectors for limited tracts.

For root maggots a teaspoonful is poured into a hole at the base of the plant, covering as above.

For ant nests an ounce of the substance is poured into each of several holes made in the space occupied by the ants, the openings being then closed, or the action is made more rapid by covering with a wet blanket for ten minutes and then exploding the vapor at the mouth of the holes with a torch, the explosion driving the fumes more thoroughly through the soil.

Submersion.—This very successful means against the phylloxera is now practiced over some 75,000 acres of vineyards in France which were once destroyed by the grape root-louse, and the production and quality of fruit has been fully restored. In this country it will be particularly available in California and in all arid districts where irrigation is practiced, otherwise it will be too expensive to be profitable. The best results are secured in soils in which the water will penetrate rather slowly, or from 6 to 18 inches in twenty-four hours; in loose, sandy soils it is impracticable on account of the great amount of water required. Submersion consists in keeping the soil of the vineyard flooded for from eight to twenty days after the fruit has been gathered and active growth of the vine ceased, or during September or October, but while the phylloxera is still in active development. Early in September eight to ten days will suffice; in October, fifteen to twenty days, and during the winter, as was formerly practiced, forty to sixty days. Supplementing the short fall submergence a liberal July irrigation, amounting to a forty-eight-hour flooding, is customary to reach any individuals surviving the fall treatment, and which in midsummer are very susceptible to the action of water.

To facilitate the operation vineyards are commonly divided by embankments of earth into square or rectangular plots, the former for level and the latter for sloping ground, the retaining walls being protected by coverings of reed grass, etc., during the first year, or until they may be seeded to some forage plant.

This treatment will destroy many other root-attacking insects or those hibernating beneath the soil, and, in fact, is a very ancient practice in certain oriental countries bordering the Black Sea and the Grecian Archipelago.

REMEDIES FOR INSECTS AFFECTING GRAIN AND OTHER STORED PRODUCTS.

The chief loss in this direction from insects is to grains in farmers' bins, or grain or grain products in stores, mills, and elevators, although in the warmer latitudes much of the injury results from infestation in the field between the ripening of the grain and its storage in bins or granaries. Fortunately, the several important grain insects are amenable to like treatment. Aside from various important preventive considerations, such as, in the South, prompt threshing of grain after harvesting, the thorough cleansing of bins before refilling, constant sweeping, removal of waste harboring insects from all parts of granaries and mills, and care to prevent the introduction of "weeviled" grain, there are three valuable remedial measures, viz, agitation of the grain, heating, and dosing with bisulphide of carbon.

The value of agitating or handling grain is well known, and whenever, as in elevators, grain can be transferred or poured from one bin into another grain pests are not likely to trouble. The benefit will depend upon the frequency and thoroughness of the agitation, and in France machines for shaking the grain violently have been used with success. Winnowing weeviled grain is also an excellent preliminary treatment.

Raising the temperature of the grain in closed retorts or revolving cylinders to 130° to 150° F. will kill the inclosed insects if continued for from three to five hours, but is apt to injure the germ, and is not advised in case of seed stock. The simplest, cheapest, and most effectual remedy is the use of bisulphide of carbon.

BISULPHIDE OF CARBON.

This is a colorless liquid with very offensive odor, which, however, passes off completely in a short time. It readily volatilizes and the vapor, which is very deadly to insect life, is heavier than air and settles and fills any compartment or bin in the top of which the liquid is placed. It may be distributed in shallow dishes or tins or in saturated waste on the top of grain in bins, and the gas will settle and permeate throughout the mass of the grain. In large bins, to hasten and equalize the operation, it is well to put a quantity of the bisulphide in the center of the grain by thrusting in balls of cotton or waste tied to a stick and saturated with the liquid, or by means of a gas pipe loosely plugged at one end, down which the liquid may be poured and the plug then loosened with a rod. In moderately tight bins no further precaution than to close them well need be taken, but in open bins it will be necessary to cover them over with a blanket to prevent the too rapid dissipation of the vapor. The bins or buildings should be kept closed from 24 to 36 hours, after which a thorough airing should be given them.

Limited quantities at a time may often be advantageously subjected to treatment in small bins before being placed for long storage in large masses, and especially whenever there is danger of introducing infested grain.

The bisulphide is applied at the rate of 1 pound to the ton of grain, or a pound to a cubic space 10 feet on a side.

In the case of mills, elevators, or larger granaries the application may be best made on Saturday night, leaving the building closed over Sunday, with a watchman without to see that no one enters and to guard against fire. The bisulphide should be first distributed in the lower story, working upward to avoid the settling vapor, using the substance very freely, in waste or dishes, at all points of infestation and over bins throughout the building.

This insecticide may also be used in other stored products, as pease, beans, etc., and very satisfactorily where the infested material can be inclosed in a tight can, chest or closet for treatment.

The bisulphide costs, in 50-pound cans, 10 cents per pound, and in small quantities, of druggists, 25 to 35 cents per pound.

Caution.—The bisulphide may be more freely employed with milling grain than that intended for seeding, since used excessively it is liable to injure the germ. It must always be remembered that the vapor is highly inflammable and explosive, and that no fire or lighted cigars, etc., should be in the building during its use. If obtained in large quantities it should be kept in tightly closed vessels and away from fire, preferably in a small outbuilding.

CONTROL OF INSECTS BY CULTURAL METHODS.

It is much easier to ward off an attack of insects or to make conditions unfavorable for their multiplication than to destroy them after they are once in possession; and in controlling them, methods and systems of farm and orchard culture have long been recognized as of the greatest value—more so even than the employment of insecticides, which, in most cases, can only stop an injury already begun. Insects thrive on neglect, multiply best in land seldom or never cultivated, and winter over in rubbish, prunings, or the undisturbed soil about their food plants, and become, under these conditions, more numerous every year. It is a fact of common observation that it is the neglected farm, vineyard, or orchard filled with weeds or wild growth which is certain to be stocked with all the principal insect enemies; and, on the other hand, thorough and constant culture, with the removal and burning of prunings, stubble, and other waste, the collection and destruction of fallen and diseased fruit, and the practice, where possible, of fall plowing to disturb the hibernating quarters of field insects, will almost certainly be accompanied by comparative immunity from insect pests.

The vigor and healthfulness of plant growth has also much to do with freedom from insect injury, such plants seeming to have a native power of resistance which renders them, in a measure, distasteful to most insects, or at least able to throw off or withstand their attacks. A plant already weakened, however, or of lessened vitality from any cause, seems to be especially sought after, is almost sure to be the first affected,and furnishes a starting point for general infestation. Anything, therefore, which aids good culture in keeping plants strong and vigorous, such as the judicious use of fertilizers, will materially assist in preventing injury.

To the constant cropping of large areas of land year after year to the same staple is largely due the excessive loss from insects in this country as compared with European countries, because this practice furnishes the best possible conditions for the multiplication of the enemies of such crops. A most valuable cultural means, therefore, is a system of rotation of crops which will prevent the gradual yearly increase of the enemies of any particular staple by the substitution every year or two of other cultures not subject to the attacks of the insect enemies of the first.

With such insects as the Hessian fly, the squash borers, and many others which have regular times of appearance, much can be done, also, by the planting of early or late varieties, or by deferring seeding so as to avoid the periods of excessive danger. Wherever possible, varieties should be selected which experience has shown to be resistant to insect attack. Familiar illustrations of such resistant varieties in all classes of cultivated plants will occur to every practical man, and a better instance of the benefit to be derived from taking advantage of this knowledge can not be given than the almost universal adoption of resistant American vines as stocks for the regeneration of the vineyards of France destroyed by the phylloxera.

In the case of stored grain pests, particularly the Angoumois moth, or so-called fly weevil, the chief danger in the South is while the grain is standing in shock or stack, after harvesting, during which period the insects have easy access to it. This source of infestation may be avoided by promptly threshing grain after harvesting and storing it in bulk. This will prevent the injury of more than the surface layer, as the insects are not likely to penetrate deeply into the mass of the grain.

These general notes are by no means new, but their importance justifies their repetition, as indicating the best preventive measures in connection with the remedial ones already given.

THE PROFIT IN REMEDIAL MEASURES.

The overwhelming experience of the past dozen years makes it almost unnecessary to urge, on the ground of pecuniary returns, the adoption of the measures recommended in the foregoing pages against insects. To emphasize the value of such practice, it is only necessary to call attention to the fact that the loss to orchard, garden, and farm crops frequently amounts to from 15 to 75 per cent of the entire product, and innumerable instances could be pointed out where such loss has been sustained year after year, while now, by the adoption of remedial measures, large yields are regularly secured with an insignificant expenditure for treatment. It has been established that in the case of the apple crop, spraying will protect from 50 to 75 per cent of the fruit which would otherwise be wormy, and that in actual marketing experience the price has been enhanced from $1 to $2.50 per barrel, and this at a cost of only about 10 cents per tree for labor and material.

In the case of one orchard in Virginia, only one-third of which was sprayed, the result was an increase in the yield of sound fruit in the portion treated of nearly 50 per cent, and an increase of the value of this fruit over the rest of 100 per cent. The loss from not having treated the other two-thirds was estimated at $2,500. The saving to the plum crop and other small fruits frequently amounts to the securing of a perfect crop where otherwise no yield whatever of sound fruit could be secured.

An illustration, in the case of field insects, may also be given where, by the adoption of a system of rotation, in which oats were made to alternate with corn, the owner of a large farm in Indiana made a saving of $10,000 per year, this amount representing the loss previously sustained annually from the corn root-worm. The cotton crop, which formerly in years of bad infestation by the leaf-worm was estimated to be injured to the extent of $30,000,000, is now comparatively free from such injury, owing to the general use of arsenicals.

Facts of like import could be adduced in regard to many other leading staples, but the foregoing are sufficient to emphasize the money value of intelligent action against insect enemies, which, with the present competition and diminishing prices, may represent the difference between a profit or a loss in agricultural operations.

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Dec, 19, 1894

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 20.

AGRICULTURAL EXPERIMENT STATION
FEB 11 1898
UNIVERSITY OF ILLINOIS.

WASHED SOILS:

How to Prevent and Reclaim Them.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WASHINGTON:
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1894.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of the Assistant Secretary,
Washington, D. C., October 27, 1894.

Sir: In accordance with your direction I have the honor to transmit herewith for publication a bulletin upon "Washed soils: How to prevent and reclaim them," prepared under my direction, by the Divisions of Chemistry, Soils, Forestry, and Botany, for one of the series of Farmers' Bulletins of this Department.

Thousands of acres of land in this country are abandoned every year because the surface has been washed and gullied beyond the possibility of profitable cultivation. It is believed that the present bulletin, and the simple facts therein presented as to how this erosion, or washing, may be prevented, and how washed and abandoned lands may be reclaimed, will serve a useful purpose in the hands of those farmers who have these trying problems to contend with.

Very respectfully,

Chas. W. Dabney, Jr.,
Assistant Secretary.

Hon. J. Sterling Morton,
Secretary of Agriculture.

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WASHED SOILS: HOW TO PREVENT AND RECLAIM THEM.

THE EROSION, OR WASHING, OF AGRICULTURAL SOILS.

The denudation, or washing, of lands of the higher levels of the earth's surface is a process which no human precaution can wholly prevent. It has been one of the most important forces and factors in the geological changes which have so modified the surface of the earth. The present surface of the largest portion of the United States is made up of this "sedimentary" or "drift" material which has been moved from the place where it was formed through the disintegration and decay of the old crystalline rocks, by water, wind, or moving ice, and which has accumulated to a depth of hundreds or thousands of feet over nearly the entire surface of the country. It is estimated that the general surface of the land in the area of the crystalline rocks of the Piedmont Plateau has been lowered at least 2,000 feet by this continual washing. This vast amount of material has been slowly removed and deposited elsewhere by the very same agents which we are contending with to-day in our gullied fields; for this denudation, or erosion, is still going on, as it has been for ages past.

As a rule this denudation is exceedingly slow and the general level of large tracts of country is not lowered more than an inch or two in a hundred years. Where the change is as slow as this it is undoubtedly of benefit to the human race, as in the course of time it must carry off the soil which has been used over and over again for vegetation and expose fresh material to the roots of plants. With this slow change the natural forces are amply sufficient for the decay of the subsoil and for the conversion of this freshly exposed material into a good soil. When the rate of denudation is excessive, however, and more rapid than the natural decay of the subsoil material which is exposed, it may work serious injury to agricultural lands.

Along the banks of the Ohio River and in very many portions of the South hundreds of fields that were once covered with sturdy forests of oak, maple, walnut, and pine, and which bore under cultivation, after being cleared of the natural growth, large crops of wheat, maize, tobacco, and cotton, may now be seen furrowed with gullies as with the wrinkles of age, and abandoned to brush and briers.

A surface layer of good agricultural soil 6 inches deep resulting from the slow and gradual disintegration and decay of rocks and accumulation of humus may have required hundreds of years for its natural formation, and yet it is liable to be washed away in a single storm.

This excessive erosion, or washing, of lands may be prevented, and the already gullied fields may be recovered, and steep slopes of loose material may be held and prevented from washing—

(1) *By chemical means*, in the application of manures and fertilizers and in the accumulation of organic matter, which change the texture of the soil and make it more porous and more absorbent of water, so that there is less to run off over the surface.

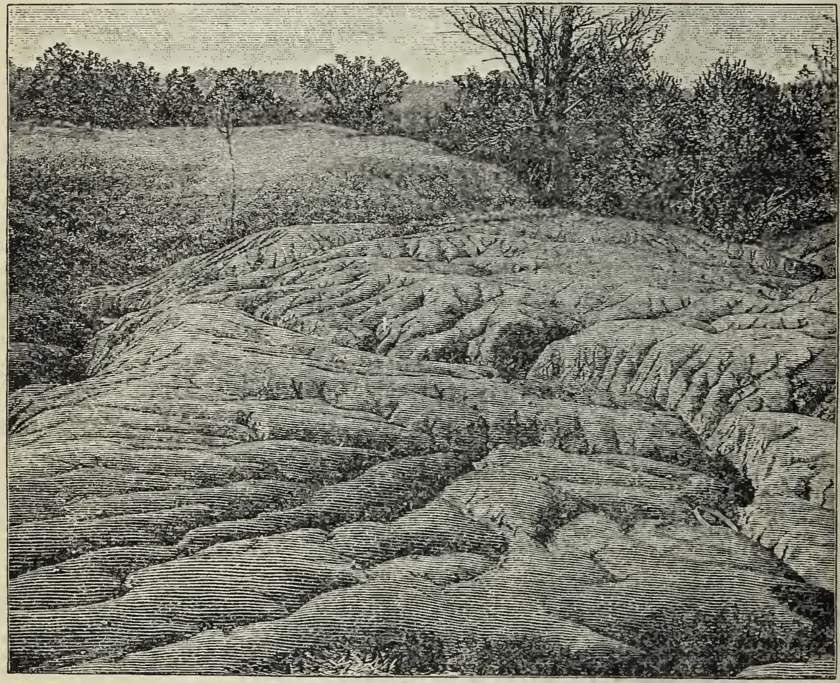

Fig. 1.—An eroded field in the South.

(2) *By means of cultivation and underdrainage*, which prevent erosion by distributing the surface flow over the ground and increase the amount carried off by underdrainage.

(3) *By reforestation*, or the planting of trees, which act mechanically to prevent washing.

(4) *By grass and similar vegetation*, which bind the soil grains and prevent their washing away.

The erosion of a soil is caused by the wearing of the rain and snow waters which can not penetrate into the soil fast enough to be carried away by underdrainage, and which, by reason of the slope or contour of the land, run off over the surface, carrying along particles of sand

and clay. When this water accumulates in a depression in the field the force of the torrent may be sufficient to cut out a great gully in a short space of time.

The extent of washing to which the soil is exposed depends upon the quantity of rainfall in a given time, the slope or contour of the surface, the texture of the soil, the vegetative covering of the surface, and the kind and condition of cultivation. A soil composed chiefly of moderately coarse grains of sand, and having good underdrainage, will absorb the heaviest rainfall without much danger of surface erosion. A clay soil, on the other hand, into which the water can not percolate with anything like the rapidity of the precipitation, will be washed and gullied by the torrent of water which must flow over the surface.

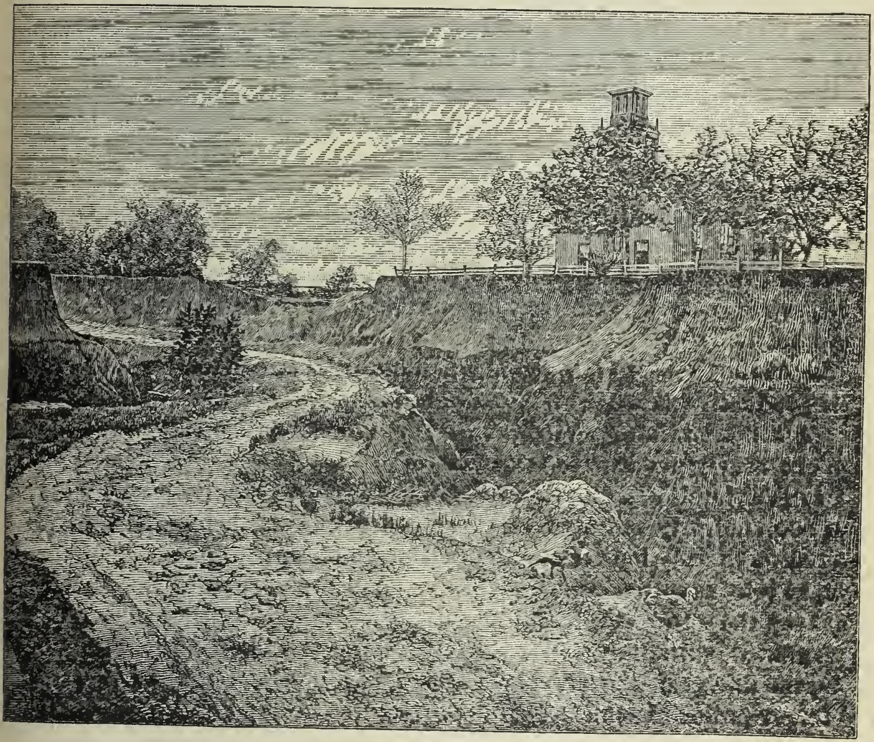

FIG. 2.—Another effect of erosion.

CHEMICAL RELATIONS OF THE SOIL TO SURFACE WASHING.

It has been repeatedly shown by experiments and by the experiences of farmers that a soil, as a rule, absorbs water more readily as the content of organic matter and of humus increases. Surface erosion can, therefore, be largely prevented by such a system of cultivation and cropping as will introduce as large a quantity of organic matter into the soil as possible. A very old method of recovering washed and gullied lands is to place straw in the furrows while plowing, the straw not only acting mechanically to hold the soil in place and prevent surface erosion, but also in a very efficient way to increase the quantity of humus, thus making the soil hold large quantities of water which otherwise would have passed off over the surface. In this simple way fields which have been badly washed and gullied and entirely abandoned may be recovered and made highly productive.

The most important thing in the recovery of waste fields is the incorporation of organic matter of some kind in the soil; pea vines, stubble, briers, or leaves from the forest may be used as a source of the organic matter. The straw from one acre of land which has been recovered, as mentioned above, will be sufficient to start the recovery of another acre, even if this be deeply furrowed with gullies. Where enough organic matter can be used as a surface dressing, this layer helps greatly to retain water and to make the underlying soil more absorbent.

As soon as a sufficient supply of humus has been accumulated and the lands are brought up to an adequate condition of fertility, clover or grass should be seeded, if the land is at all suited to these crops, or rye, oats, or field peas should be sown to help hold the surface. Little by little, but more rapidly than would be expected from the forbidding aspect of the field, the land can be reclaimed again and made productive through the accumulation of humus and organic matter. A soil containing a fair quantity of humus will wash less readily than one nearly destitute of this matter.

A soil containing a fair supply of lime is much less liable to wash than one similarly situated and exposed which is deficient in lime. The reason of this is that clays which are deficient in lime, when once brought into suspension by moving waters, will remain in suspension and keep the water turbid for a long time. Clays which are heavily impregnated with lime salts, on the other hand, are in a flocculated state, the fine grains of clay being held together and in contact with the larger grains of sand. This flocculated mass quickly settles and is originally not so easily disturbed and carried off by moving water. A field treated with an abundance of lime is thus less easily washed by heavy rains. The results of investigations by Schulze, Schloesing, and Hilgard have shown in a most emphatic way the beneficial changes which take place, especially in stiff clay soils, by the application of lime.

The change in the physical condition of the soil which is produced by the lime, and which is likewise produced by a number of other chemicals ordinarily used in commercial fertilizers, is another important factor worthy of consideration. A stiff clay soil is practically impervious to the penetration of surface water when it is delivered in such torrents as we are liable to have in our summer storms. A well-limed soil, on the contrary, although it may contain as much clay but in which the particles are flocculated or drawn together, is much more pervious to water, and the amount of water which the soil will carry down through underdrainage is increased, and the excess which has to flow off over the surface is diminished. The surface washing of cultivated fields, especially those which are naturally deficient in lime, can be greatly diminished, therefore, by the free application of this substance to them.

A number of the ordinary fertilizing materials have an important effect upon the texture of soils and upon the permeability of soils to water, but few systematic investigations have been carried on in this line and not much, except of local importance, has been definitely settled by experiments or by the experiences of farmers.

WASHING OF LANDS MAY BE PREVENTED BY METHODS OF CULTIVATION AND UNDERDRAINAGE.

The depth and character of the tillage are very important factors in the washing of lands. A field in a condition of fine tilth and plowed to a depth of 10 inches will hold 2 inches of rainfall and absorb it very readily, and a soil in such a condition will suffer no surface washing from any ordinary rainfall. Where it is possible, therefore, land which is apt to wash should have the soil gradually deepened and be kept in a fine state of tilth so as to increase the storage capacity for excessive precipitations. This will not only save the surface from being washed and gullied, but it will also increase the store of moisture held by the soil, which is of very great value in the time of drought.

It is important also for this, as for other reasons, that the soil be covered with vegetation as much as possible throughout the year, as the roots and organic matter serve to bind the grains of the soil together. In some parts of Holland the drifting sands of the coast, which shift their position with every storm, often cover up valuable farming lands. Vast areas of these sands have been reclaimed and made productive by being covered with vegetation, while the roots and remains of organic matter hold the soil grains in place and prevent them from drifting and covering up more valuable lands. Any crop which requires very clean culture, as for example, cotton, is exhausting to the land for the reason that constant exposure of the surface to the sun and storms uses up the organic matter, makes the soil less porous, and the soil particles themselves are more easily washed away; so that, this clean cultivation is in its effects very favorable to excessive erosion. With crops which require such clean cultivation it is very advantageous to sow some crop like rye in the field during the last working of the crop both to bind the surface and protect it from washing in the winter and for other benefits which such a covering provides.

Another very effective method, when properly carried out, to prevent the washing of lands is to underdrain the soil with tile or other drains. These drains carry off quite rapidly an excess of moisture, so that much more of the rainfall is absorbed by the soil and carried off through the drains and less washes over the surface of the land. Not only this, but a well-underdrained field is usually dryer and more porous, and has a greater capacity for absorbing the excessive rainfall and thus preventing surface washing. A field thoroughly underdrained with tile drains will carry off the water of any ordinary rainfall without any surface erosion. This method is very effective, but is likewise very expensive, and can not be used economically in extensive farming solely for this purpose of protecting the land from washing.

While the land may thus be made more porous and more absorbent of water—through the increase of the amount of organic matter or of humus, through the use of lime and other fertilizing material, through the deepening of the soil by gradually increasing the depth of cultivation, by so cropping it that it shall be covered with vegetation as much of the year as possible, and by underdraining the land—still, these methods may not be sufficient to so change the chemical and physical texture of the soil as to enable it to absorb the rain as it falls and to prevent an excess of water washing and eroding the surface where the contour of the land is such as to promote erosion from the surface flow of the excess of water.

It will be necessary in this case to provide for a more uniform distribution of the flow over the surface, and to prevent any accumulation of water which would have the effect of a torrential stream. This is secured in a great measure by laying off the rows according to the contour of the surface, so that each row will have a very slight incline of not more than from 1 to 6 inches in 100 feet, and in which the flow of water would be so slow that there would be little or no erosion. Theoretically, this is a fine idea, to let each row carry off its own proportion of the excess of rainfall so gently that there shall be no erosion, thus acting as a minature drain. Practically, however, it is often impossible to keep these rows from breaking through, and when the bed is once broken and the water overflows into the next row the accumulation of water is sufficient to break down bed after bed until the rows from all the field are discharging into this narrow channel.

To overcome this difficulty sidehill ditches may be used in which larger and more substantial ditches are provided, following very nearly the contour of the field, so that there shall be a fall of from 1 to 6 inches in 100 feet. The distance apart of the ditches will depend upon the slope of the field; with a very steep slope they should be close together, often not over 6 to 10 feet apart; with a gentle slope they should be at intervals of 15 or 20 feet, or even farther apart, depending upon the texture of the soil and the contour of the surface.

These sidehill ditches are very easily constructed, being made almost entirely with the plow. A bank is formed by running a number of furrows, throwing the dirt toward the middle. The last furrow on the upper side is cleaned out with a spade to form the bottom of the ditch. If the plow is well handled it takes very little work with the spade to make a very substantial ditch. It is well to get the bank forming the lower side of the ditch sodded with grass to help hold it and to lessen the danger of its giving way during a heavy rainfall. When the slope is thus protected with a number of ditches at the proper distance apart, the rows can be given a rather steeper fall so that they shall run out into the drains at frequent intervals and not have to carry the water so far. These ditches have to be constructed with care and have to be strengthened where they cross any depression or sudden curve by building up an embankment with sticks and brush thrown across to support the embankment. Unless these ditches are thoroughly constructed they are worse than useless, for if they break they concentrate a volume of water upon one point in the field which would otherwise have been distributed over the surface, and this often forms a torrent which does great damage.

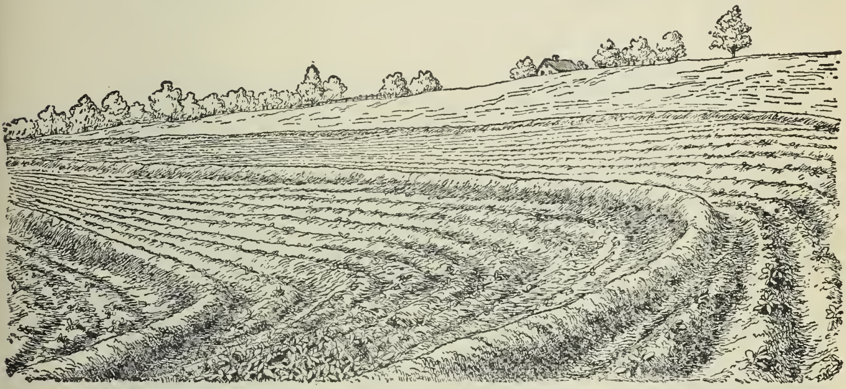

Fig. 3.—Showing construction of sidehill ditches.

It is essential that these ditches and rows be run according to the contour of the surface of the land, and that there shall be no low places where the water would accumulate and gather force. They should always be run with a level, of which there are several forms on the market suitable for this work.

A more efficient, but at the same time much more expensive, method of preventing the washing of lands where there is a considerable slope, is to terrace the fields so that there shall be level steps upon which the water can rest for a while and be absorbed. In terracing the lines are run with a spirit level following the contour of the surface so as to give a perfectly level line. A furrow is run along this line, and a similar furrow is run along a lower contour, the distance apart depending upon the nature of the land and the slope of the surface, as in case of sidehill ditches. Theoretically, it is intended to have the surface between these two furrows level so that there will be no chance for the water to run off over the surface. On a small scale this leveling can be done with a horse shovel, and the land thus put at once into a condition to pre.

vent washing. In this case the banks of the terrace are sodded or seeded with grass to prevent them from washing. In field practice, however, the soil is moved gradually with a plow, the furrow being thrown always downhill and the soil gradually worked down to a level plain. There are several forms of reversible plows which are admirably adapted to this purpose, being turned readily from a right to a left handed plow, so that in going back and forth the furrow is always thrown downhill. It requires, of course, a number of years of such cultivation to get the surface into even approximately a level condition, but with patience and thorough cultivation the soil very quickly assumes a comparatively level aspect, and erosion is reduced to a minimum. This is a more expensive method, but if intelligently done it is much more efficient and much more durable than depending upon sidehill ditches to prevent erosion. As was said in the case of the sidehill ditches, unless this work is well done it had much better be left undone, as it may seriously injure the field.

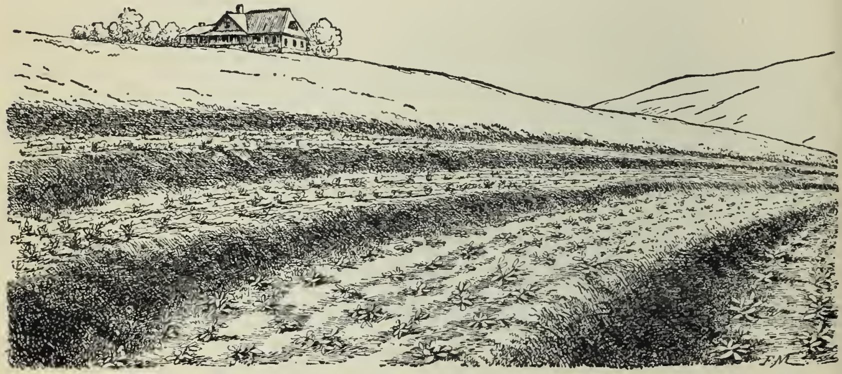

FIG. 4.—Showing method of terracing farm lands.

Where erosion has proceeded so far as to render the land at present unfit for cultivation, or where the land is not needed for cultivation and it is desired to prevent erosion, the land should be given up to trees, herbs, or grasses of some kind according to one or the other of the following methods.

RECOVERING GULLIED HILLSIDES BY REFORESTATION.

Forest ground is not subject to this erosive action of the rainfall because in a forest a large part of the rainfall never reaches the soil, as 20 or 30 per cent is intercepted by the foliage and evaporated before it reaches the ground. The rainfall which reaches the surface is rapidly absorbed, as the soil is kept granular and loose and much more of the water is carried off by underdrainage rather than by surface drainage.

The forest covering protects the soil in the following ways:

(1) By preventing rain from falling directly upon the soil, the foliage

of the tree crowns intercepting and breaking its force, the water reaching the soil more gently from the leaves and along the branches and trunks of the trees.

(2) By interposing a loose cover or mulch of litter formed by the fallen leaves and branches, which breaks the direct force of the raindrops and keeps the soil from being compacted or puddled by their blows.

(3) The deeply penetrating roots, and holes left from decayed stumps and roots of trees, assist in this underground drainage.

(4) The litter with the stumps and projecting roots and trunks of trees prevent the water from rapidly running over the ground and from gaining the momentum and force which is necessary in order to erode and gully the soil.

(5) The forest cover prevents the drifting and the rapid thawing of snow, thereby insuring more even distribution of the waters and an increase in the time during which it can percolate or be absorbed into the soil.

If the forest floor is not disturbed by fire, nor the litter trampled and compacted by cattle, it always reduces rapid surface drainage and largely, if not entirely, prevents erosive action.

RECOVERY OF WASHED SOILS.

Just as deforestation of hillsides and hilltops is the first cause for inducing erosive action, so is reforestation the most effective means in curing the evil. This has been demonstrated in France, where the Government and the farmers together have spent, during the last thirty years, over $40,000,000 and expect to expend three or four times that amount to reforest 1,000,000 acres of denuded mountain sides, the soil and débris from which has been carried by the torrents of water into the plain, covering over 8,000,000 acres of fertile ground and making it useless for agriculture. Sodding for pasture has been found mostly less effective and on the steeper slopes entirely ineffective.

Wherever the ground in the hill country is not fit for agricultural use it should be set and kept in forest, not only to make it produce a timber crop, but also to prevent the erosion which finally becomes dangerous to the lower valley lands. Wherever agriculture is possible and profitable there should be such a distribution of forest, pasture, and field as will secure the greatest immunity from erosive and torrential action of the waters. The forest should occupy all hilltops which, as a rule, have too thin a soil to allow profitable agricultural use; it should be kept growing on the steeper slopes where the water acquires the greatest momentum and the loosening of the soil by the plow furnishes a most favorable condition for erosive action; it should be placed on all rocky, uneven, agriculturally useless spots, because it will produce useful material even on such unfavorable situations, and, finally, forest belts should be maintained on long slopes alternately with fields and pastures, running along the brow of the slope of widths and at distances proportionate to the character of the land and the angle of the slope—on the steeper slopes closer together, on the gentler slopes further apart. These belts, acting as a barrier to break the force of the water, will prevent an undue accumulation of surface waters and will protect to a considerable degree the lower fields from washing. Farmers, therefore, living in the eroded hill country should start upon the work of reforestation with a well-conceived plan. They should determine beforehand which parts ought to be in forest, and which they may reasonably expect to adapt again to agricultural uses. They should understand that they must begin this work at the origin of the evil, at the very tops of the hills where the water begins to gather and acquire its force, and gradually proceed with their work down to the lower levels.

PREPARATION FOR PLANTING FORESTS.

Although cultivation of the soil for tree planting in the manner practiced for field crops is advantageous to the young plants for the first few years of their life, it is by no means necessary, and rough, broken, and stony ground, which could not be plowed and prepared for ordinary field crops can be readily planted in trees. If the ground is in such a condition that it can be plowed, this is decidedly the best method of preparing the land. The plowing should in all cases follow the contour of the hill and be as deep as possible, in order to allow as much water as possible to soak into the soil and so diminish surface erosion and prevent the young trees being washed out. The occasional gullies must be filled with brush and soil, or stones, rubble, and dirt.

In the deeply gullied hill lands, where plowing has become impracticable, other ways must be provided against the further erosive action of the water, which would otherwise be apt to wash out and uproot the plants. For this purpose it is necessary to break the force of the water by constructing brush dams across the gullies, and roughly fill in the latter with stone, gravel, earth, etc., in front and rear if they are shallow, and at least in the rear if they are deeper. Where the ravines are especially deep and wide it may become necessary to supplement and strengthen the rough dam with a loose rubble embankment or a dry wall of stone. A simple and efficient method has been practiced in France, which consists in filling up the ravine with brush placed lengthwise and keeping this down by poles laid across and fastened in the sides of the ravine. The waters are thus allowed to drain off, while the soil carried by them is retained in and over the brush, and in a short time the gulley will fill up of its own accord. Then alders and willows are planted along the edge and soon finish the work of securing the ravine against washing. The means for thus breaking the force of the water in the gullies and changing it from a rushing torrent into a series of gentle falls, and in part from surface drainage into subterranean drainage, and of filling up the gullies themselves will have to be devised in every special case as circumstances permit and the ingenuity of the operator suggests. The brush dam is preferably made of willow, poplar, alder, or other readily sprouting material, which becomes alive and by striking root adds to the firmness of the dam.

It is especially needful, as in all kinds of dams, to fasten the ends securely. According to the steepness, depth, and width of the ravine more or less frequent dams are necessary. The accompanying illustration shows how such work is being done successfully in France. After the brush dams, walls, and other breastworks have been established, the waters may be allowed to do the work of filling up the gullies themselves, which they will do sooner or later, or else, where it can be readily accomplished, the filling may be done by hand.

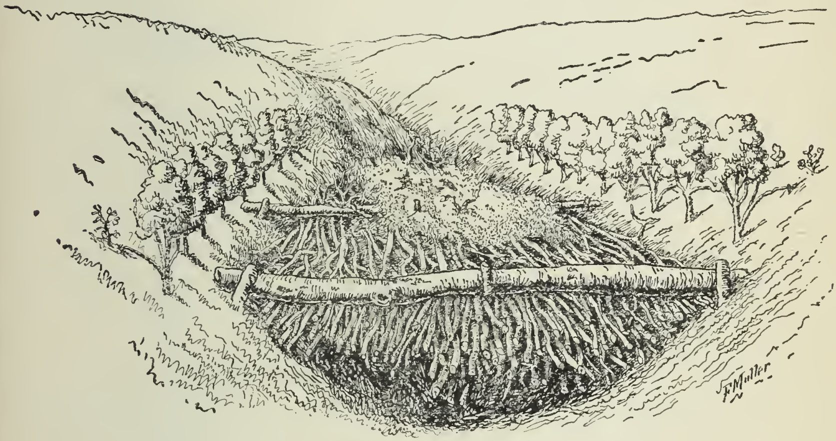

FIG. 5.—Construction of a brush dam.

It must be understood that unless this preliminary work is well done and systematically, beginning at the very tops of the hills where the waters start, it is not worth doing at all, since the water if allowed to get headway would soon wash away and destroy any imperfect work.

PLANTING.

To cover the soil as quickly as possible with a dense and permanent arborescent cover is the object to be attained. Where the soil has not been so far eroded that plowing could be done, it might be best for the first season to sow oats, field peas, or other crops that will readily grow and make a cover. This may be cut for green fodder, leaving a high stubble, and tree seed can be sown broadcast with the fodder crop in the early summer, or over the stubble after the crop is cut in the late summer and fall. The cheapest and most readily germinating tree seed should be looked for and the quantity used per acre should be lavish, to secure a dense stand from the first. The most readily available kinds are the silver or red maple, box elder, elms, ash, and black locust; and since for various reasons variety or mixed woods are preferable, it is advisable to use as many kinds as can be readily obtained.

The soft and red maples ripen their seed in early spring, just about when the leaves are at full size, and should be gathered and sown immediately, as they spoil in a short time. Sown with a field crop they will make a good growth the first year, benefited by the shade of the crop. To provide amply for loss by failure and by destruction when reaping the field crop, not less than three to four bushels per acre of the winged seed should be sown.

The elms ripen their seed in the early summer, by the end of May or beginning of June. As they spoil in a few hours, if allowed to heat in bags, they must be carefully handled and be sown soon after ripening. The same quantity should be sown as of the maples, or somewhat more, and they may be sown after the maples. The box elder is a very hardy and densely foliaged plant which ripens its seed in the early fall. They should be sown soon after ripening at the same rate as the maples. Of the several varieties of ash, the green and white are to be recommended, especially the former, which bears fruit early and plentifully, and is perhaps more hardy than the white. The latter is, however, superior in its timber. The seed ripens by the end of September and the beginning of October, and although it will keep over winter, it is best sown soon after gathering, when the rains and winter snows will carry it through the stubble to germinate next spring.

Finally, with a view to adding a more valuable species, which at the same time is readily procured and propagated, the black locust should be introduced. The seeds ripen in July or August and have the advantage of keeping readily in good condition, and may therefore be sown at any time, but are best used soon after ripening. This species should never be planted alone, because it does not shade the ground well, but when mixed with other shadier kinds, which by their fuller foliage give better soil protection and at the same time reduce the danger from the borer, to which the black locust is otherwise liable, it is one of the most useful species for the purpose, because it grows readily and quickly and suckers and sprouts vigorously, thus insuring a continuous soil cover. With a tolerably dense cover of other species assured, an addition of one or two pounds per acre of locust seed will greatly enhance the economic value of the plantation.

Where the ground is too much cut up and too uneven to permit of plowing, recourse must be had to sowing of seed in plats, or planting of seedlings or cuttings by hand. This is naturally much more expensive, and therefore should be done with greater care and foresight. Plats may be made by loosening the soil with a hoe or spade, and sowing the seed into these seed beds, covering the seed only slightly. The plats should be 3 to 4 feet apart to make sufficiently rapid cover. The success of this method is, however, very questionable, as not only the germinating of the seed under the prevailing conditions is precarious, but rains are apt to wash out the seed or young seedlings. The best success may perhaps be obtained with black locust or oak, the seed of which can be placed deeper (1 to 2 inches) according to soil conditions, with a hope of germinating and avoiding the danger of washing. The surer method, however, will be found in planting seedlings or cuttings. Seedlings are not only expensive but also more precarious to handle, hence for the bulk of the plantation such kinds as can be readily obtained and propagated by cuttings are used, and if desired a sufficient number of seedlings of better kinds can be added to increase the timber value of the plantation.

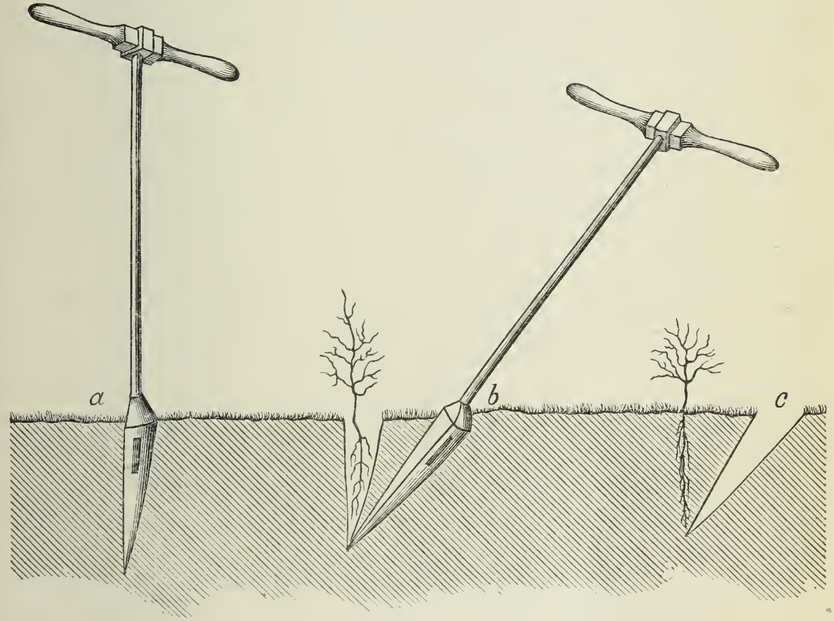

FIG. 6.—A dibble used in planting trees.

The cheapest and most readily growing material for the general cover is furnished by the willows and poplars, to which may be added the box elder, the black locust, and the catalpa, while other more valuable kinds may be introduced, when the first cover has been established, by the planting of 2 or 3 year old plants in single specimens.

The cuttings are best taken in winter before vegetation begins (before the 1st of March), and should be laid in water until planting time, in April; they should be cut 14 or 16 inches long from 3, 2, or even 1 year wood, if of good size, and preferably from the main shoots. For planting, an iron dibble with handle, somewhat like that shown in Fig. 6 is used, and a half conical shoe 12 inches long and 2½ to 3 inches in diameter is also a useful instrument. If the soil to be planted is rather compact and hard, a step may be added—to be used like a spade. The dibble is thrust into the ground to its full depth, loosened and withdrawn; a boy holds the cutting into the hole so that about two or three buds remain above ground; a second thrust somewhat slanting, 2 inches or so from the first hole, and a forward movement closes the hole and plants the cutting, while a few additional short thrusts close the last hole. Two skillful men, with a boy to serve both in placing the cuttings, can plant 3,500 in a day. Seedlings, of course, are planted in the same way.

The first and principal object being to break the force of the surface waters, the arrangement in setting out the plants should be as nearly as possible in horizontal and parallel rows along the brow of the hill, following the contours. To get a full cover as soon as possible the plants should be set not farther apart than 3 to 4 feet and even less, making from 5,000 to 7,000 per acre. If this is found too expensive, or for some reason impracticable to be done at once, the work may be reduced and divided into several seasons; the rows then may be made farther apart, say from 6 to 16 feet, according to the slope, and the plants in the row 2 feet, when the number will be one-half, or less. Additional rows and perhaps of better classes of timber, especially oaks, chestnuts, tulip trees, ash, walnut, and others may be introduced in the following seasons, the soil having come to rest by the first plantings; or else the trees and shrubs grown in the first rows can be utilized to establish a cover by layering their branches. This is done simply by bending down branches, fastening them to the ground by small wooden forks or clamps, and covering a part, say 6 or 10 inches from the end, with soil, when they will strike root and the next year the bent-down branches may be cut loose from the new stock. The branches must be covered with enough earth to insure that sufficient moisture is at their disposal for root formation; covering the buried part with a sod or a stone, which prevents evaporation, is advantageous.

Whatever is done in such a work of recovering lost ground, let this fact never be forgotten, that it is better to do a small part well than a large part indifferently, which usually means lost labor.

GRASSES AND SIMILAR VEGETATION PREVENT EROSION AND WASHING OF AGRICULTURAL LANDS.

On gentle slopes a good turf of perennial pasture grasses, especially those with creeping rootstocks, prevents erosion, or washing, of lands, and short steep embankments may also be protected with this same covering. On longer and steeper slopes, however, this method is not so effective as that of reforestation.

In enumerating the effects to be obtained by the growth of grasses and other herbaceous vegetation on washing lands, or lands liable to be eroded, it should be stated that such growths are calculated to break the force of the rainfall and prevent its packing the soil; to render the ground more porous through the root penetration into the subsoil; to make the soil more absorbent and more retentive of moisture through the addition of humus to the soil from the decay of the plants; to retard the rate with which the surface waters flow off, and lastly, to bind the particles of soil together, which is especially effective in the case of light sandy lands and of newly formed embankments, whether of sand or clay.

The turf which would answer the present purposes should be composed of perennial grasses of varieties which have creeping rootstocks, and it is frequently essential that they be able to grow upon an impoverished and often hard soil. To secure a strong turf on lands of this character it is very important that the soil be put into the best possible condition. Where practicable the soil should be thoroughly plowed or loosened, and some variety of field pea or clover be seeded down, such as the cowpea, Japan clover, or the crimson clover, all well adapted to this purpose. These crops may either be cut off, leaving a high stubble to be turned under, or the whole may be plowed under, thus furnishing a quantity of organic matter to the soil as a preparation for the grasses which are to be seeded. As drought is one of the most serious conditions to be contended with on lands of this character, crimson clover is one of the best of these green manuring crops, as it makes most of its growth in the winter months, when there is less liability of drought. This, however, can not be used too far North, as it does not stand the winters well.

With this preparation of the soil Bermuda grass is one of the best grasses for the purpose of preventing erosion, or of reclaiming eroded land in the South. This should be planted by cutting up a turf rather than by seeding, as the seeds do not germinate very readily, even where they have been gathered in a mature condition. Care must be taken in the introduction of this Bermuda grass, as it is exceedingly troublesome in the cotton field. In the North the English blue grass is one of the best grasses for this purpose, and the Hungarian brome is valuable for the same purpose in both localities.

Where the soil will support other good turf grasses of higher value for hay or pasturage, or where the soil can be brought into a condition to support them, these more valuable grasses should be introduced.

FARMERS' BULLETINS.

Applications for bulletins of this series should be addressed to the Secretary of Agriculture, Washington, D. C.

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Farmers' Bulletin No. 16. Leguminous Plants for Green Manuring and for Feeding. Pp. 24. Issued April, 1894.

Farmers' Bulletin No. 17. Peach Yellows and Peach Rosette. Pp. 20. Issued May, 1894.

Farmers' Bulletin No. 18. Forage Plants for the South. Pp. 30. Issued August, 1894.

Farmers' Bulletin No. 19. Important Insecticides: Directions for Their Preparation and Use. Issued July, 1894.

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 21.

BARNYARD MANURE.

BY

W. H. BEAL,
Of the Office of Experiment Stations.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., September 25, 1894.

Sir: I have the honor to transmit herewith for publication as a Farmers' Bulletin an article on barnyard manure, prepared under my direction by W. H. Beal, of this Office. I feel sure that the importance of the manure produced by domestic animals in the economical management of our farms is not sufficiently appreciated, and hope that the presentation of the case in the light of the best practice allied to the most thorough research will serve to increase the attention paid to this essential element in successful farming. This bulletin will also supplement the information given in Farmers' Bulletin No. 16, on Leguminous Plants for Green Manuring and for Feeding.

Respectfully,

A. C. True,
Director.

Hon. J. Sterling Morton,
Secretary of Agriculture.

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BARNYARD MANURE.*

MANURE AS A FARM RESOURCE.

A well-kept manure heap may be safely taken as one of the surest indications of thrift and success in farming. Neglect of this resource causes losses, which, though vast in extent, are little appreciated. Waste of manure is either so common as to breed indifference or so silent and hidden as to escape notice.

According to recent statistics there are in the United States, in round numbers, 16,000,000 horses, 53,000,000 cattle, 45,200,000 hogs, and 45,000,000 sheep. Experiments indicate that if these animals were kept in stalls or pens throughout the year and the manure carefully saved the approximate value of the fertilizing constituents of the manure produced by each horse annually would be $27, by each head of cattle $19, by each hog $12, and by each sheep $2. The fertilizing value of the manure produced by the different classes of farm animals of the United States would, therefore, be for horses, $432,000,000; cattle, $1,007,000,000; hogs, $542,400,000; and sheep, $90,000,000, or a total of $2,071,400,000.

These estimates are based on the values usually assigned to phosphoric acid, potash, and nitrogen in commercial fertilizers, and are possibly somewhat too high from a practical standpoint. On the other hand, it must be borne in mind that no account is taken of the value of manure for improving the mechanical condition and drainage of soils, which, as the subsequent pages will show, is fully as important a consideration as its direct fertilizing value.

Discussing this subject from a more practical standpoint, Prof. Roberts has suggested $250 as a conservative estimate of the value of the manure produced during seven winter months on a small farm carrying 4 horses, 20 cows, 50 sheep, and 10 pigs.

If we assume that one third of the value of manure is annually lost by present methods of management, and this estimate is undoubtedly a conservative one, the total loss from this source in the United States, as indicated by the first figures, would be about $690,466,000; or, using Roberts's figures, the annual loss for each farm would amount to $83.33.

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*In this bulletin the term "barnyard manure" is used to mean the solid and liquid excrement of farm animals either alone or mixed with litter and more or less fermented.

It should be clearly understood that when the farmer sells meat, milk, grain, hay, fruits, vegetables, etc., from his farm, or neglects to save and use the manure produced, he removes from his soil a certain amount of potash, phosphoric acid, and nitrogen that must be restored sooner or later if productiveness is to be maintained.

The following table compiled by Armsby shows the amount and value of fertilizing constituents carried away from the soil in different products:

Manurial value of farm products.

	Pounds per ton.			Value per ton.				Manurial value of $10 worth.
	Nitrogen.	Phosphoric acid.	Potash.	Nitrogen.	Phosphoric acid.	Potash.	Total.	
Meadow hay	20.42	8.2	26.4	$3.47	$0.57	$1.06	$5.10	$5.10
Clover hay	40.16	11.2	36.6	6.83	0.78	1.46	9.07	9.07
Potatoes	7.01	3.2	11.4	1.19	0.22	0.46	1.87	0.12
Wheat bran	49.15	54.6	28.6	8.35	3.82	1.14	13.31	8.32
Linseed meal	105.12	32.2	24.8	17.87	2.25	0.99	21.11	7.54
Cotton-seed meal	135.65	56.2	29.2	23.06	3.93	1.17	28.16	10.05
Wheat	37.53	15.8	10.6	6.38	1.11	0.42	7.91	2.63
Oats	36.42	12.4	8.8	6.21	0.87	0.35	7.43	3.86
Corn	33.06	11.8	7.4	5.62	0.83	0.30	6.75	3.78
Barley	39.65	15.4	9.0	6.74	1.08	0.36	8.18	3.03
Milk	10.20	3.4	3.0	1.73	0.24	0.12	2.09	0.88
Cheese	90.60	23.0	5.0	15.40	1.61	0.20	17.21	0.69
Live cattle	53.20	37.2	3.4	9.04	2.60	0.14	11.78	1.18

> We learn from the above table [says Armsby] that the farmer who sells a ton of hay, for example, sells in this ton of hay fertilizing ingredients which, if purchased in the form of commercial fertilizers, would cost him about $5.10; that if he sells 2,000 pounds of wheat he sells an amount of nitrogen, phosphoric acid, and potash which it would cost him $7.91 to replace in his soil in the form of commercial fertilizers. Or, looking at it from a somewhat different standpoint, a farmer who sells, for example, $10 worth of wheat sells with it about $2.63 worth of the fertility of his soil. In other words, when he receives his $10 this amount does not represent the net receipts of the transaction, for he has parted with $2.63 worth of his capital, that is, of the stored-up fertility of his soil, and if he does not take this into the account he makes the same mistake a merchant would should he estimate his profits by the amount of cash which he received and neglect to take account of stock.

If the farmer, instead of selling off his crops, feeds them to live stock on the farm as far as possible, a large proportion of this fertility, as has been shown above, is retained on the farm; and "if the business of stock feeding is carried to the point where feed is purchased in addition to that grown on the farm, a considerable addition may in this way be made to the fertility of the farm at an almost nominal cost, since it is assumed that feed will not be bought unless its feeding value will at least pay its cost." This commendable system of indirect purchase of fertilizers in feeding stuffs is practiced largely in England and other European countries, and accounts for no small share of the profits of stock-raising in those countries.

But it is evident that these advantages will not be secured unless the manure produced is carefully saved and used.

The growing of more leguminous plants, such as beans, peas, clover, lupines, etc., as a means of increasing the fertility of the soil, is strongly recommended both from theoretical and practical considerations, but as a recent farmers' bulletin (No. 16) of the Department says:

> The leguminous crop is best utilized when it is fed out on the farm and the manure saved and applied to the soil. The greatest profit is thus secured and nearly the same fertility is maintained as in green manuring. * * * The farmer should mend his system so that the barnyard manure will be as well cared for as any other farm product. Loss from surface washing, leaching, fermentation, and decay should be guarded against. Then the feeding of richer food will mean richer manure and better and cheaper crops.

It is hard to persuade the farmer to abandon time-honored practices and adopt methods with which he is unfamiliar. He also hesitates about incurring the necessary expense of building suitable receptacles for the storage of manure, frequently assuming that this is greater than it really is. As Roberts states "the new idea that the manure should be as carefully preserved from unnecessary waste as any other product of the farm is hard to put in practice, after having stored for forty years the farmyard manure under the eaves upon the steep hillside which forms one border of the running brook."

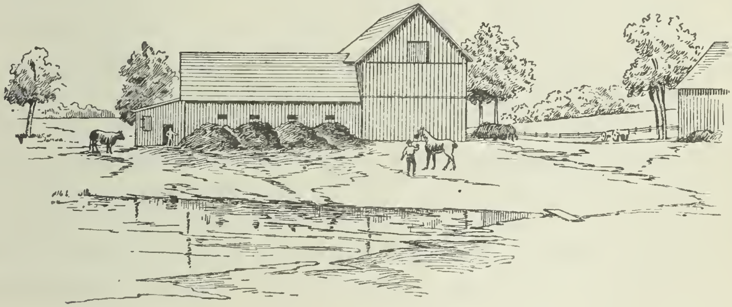

FIG. 1.—The waste of barnyard manure.

It is to be feared that the introduction of commercial fertilizers has not been without effect in increasing the apparent indifference with which this valuable farm resource is so often regarded. Too many farmers lose sight of the fact that, as a rule, commercial fertilizers should supplement and not entirely replace the manurial supplies of the farm.

AMOUNT, VALUE, AND COMPOSITION OF MANURE PRODUCED BY DIFFERENT ANIMALS.

It is of great importance to the farmer to know the amount and value of manure which will be produced in a given time by animals of different kinds, and various methods of calculating these approximately have been proposed. Some authorities base their calculations upon the amount of straw used as litter, assuming that for 1 ton of straw used as bedding, 4 tons of manure will be produced. Armsby shows, from carefully conducted experiments with horses, that where straw is used as economically as possible each horse will require 2,500 pounds of straw per year for bedding purposes. Using this as a basis, he calculates "that a ton of wheat straw, economically handled, may result in 6 tons of fresh manure," but under ordinary circumstances it will probably not result in more than 5 tons. "In stables where but one or two horses are kept or where the manure is infrequently hauled away, the product might not greatly exceed 2½ tons when the time came to remove it."

Probably the most accurate method which has been used is that adopted by Heiden and others, which bases all calculations upon the amount of food consumed and litter used.

The dried excrement of horses, cows and other neat cattle, and sheep is nearly one half of the dry food consumed. One hundred pounds of dry matter in food consumed by horses yields 210 pounds of manure, containing on an average 77.5 per cent of moisture. To this should be added the weight of bedding (amounting to about 6½ pounds per day) in order to get the total product of manure. Making allowances for dung and urine dropped outside of the stable, Heiden calculates that a well-fed working horse will produce 50 pounds of manure per day, or 6½ tons per year, which can be saved. Boussingault's and Hofmeister's figures indicate this amount to be 5¼ to 5½ tons; while Armsby's put it at about 6⅓ tons. Cows and other neat cattle produce manure containing on an average 87.5 per cent of water. One hundred pounds of dry matter consumed in food yields 384 pounds of manure, to which must be added the amount of litter used, which, according to Heiden, should be about one third of the dry matter fed. Calculating on this basis, a steer weighing 1,000 pounds and consuming 27 pounds of dry matter per day would produce about 20 tons of manure per year.

Sheep excrete 49⅓ per cent of the dry matter of their food. The manure contains on an average 73 per cent of water. One hundred pounds of dry matter in the food would therefore produce 183 pounds of manure. A 60-pound sheep, fed 2 pounds of dry matter and receiving three fifths pound of bedding, would produce about 4.1 pounds of manure per day, or three fourths ton yearly.

Careful observations have indicated that the pig produces from 12 to 16 pounds of manure per day, or from 2 to 3 tons per year.

The following table compiled from a bulletin of the New York Cornell Station shows the amount and value of manure produced by the principal kinds of farm animals fed liberally and given sufficient bedding to keep them clean, calculated to a uniform basis of 1,000 pounds live weight:

Amount and value of manure produced per 1,000 pounds of live weight of different animals.

	Amount per day.	Value per day.*	Value per year.*
	Pounds.	*Cents.*	
Sheep	34.1	7.2	$26.09
Calves	67.8	6.2	24.45
Pigs	83.6	16.7	60.88
Cows	74.1	8.0	29.27
Horses	48.8	7.6	27.74

* Valuing nitrogen at 15 cents, phosphoric acid at 6 cents, and potash at 4½ cents per pound.

The fertilizing constituents and the value per ton of the manure obtained under the above conditions are shown in the following table, in which is inserted for comparison the results of analyses by Storer of manure of hens, which is representative of that of fowls in general:

Analyses and value per ton of manure of different animals.

	Water.	Nitrogen.	Phosphoric acid.	Potash.	Value per ton.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	
Sheep	59.52	0.768	0.391	0.591	$3.30
Calves	77.73	0.497	0.172	0.532	2.18
Pigs	74.13	0.840	0.390	0.320	3.29
Cows	75.25	0.426	0.290	0.440	2.02
Horses	48.69	0.490	0.260	0.480	2.21
Hen manure	56.00	0.80 to 2	0.50 to 2	0.80 to .90	7.07

These figures probably fairly represent the actual fertilizing value of the carefully preserved manure (both solid and liquid) of well fed and cared for animals. In all cases the manure was protected from leaching and in some cases treated with a small amount of gypsum as a preservative. "It will be noticed that the average amount of nitrogen recovered in all the manure is considerably more than that of the potash and about twice the amount of phosphoric acid."

In general practice the manure from the different kinds of animals is frequently collected in a common heap until needed. While it is difficult to state an average, mixed barnyard manure properly cared for may be safely assumed to vary in composition within the following limits:

	Per cent.
Nitrogen varies from	0.4 to 0.75
Phosphoric acid varies from	0.2 to 0.40
Potash varies from	0.4 to 0.75
Water varies from	70 to 80

COMPARATIVE VALUE OF SOLID AND LIQUID PARTS.

It is a fact often lost sight of in practice that the urine of animals is by far the most valuable part of the excreta. The solid excreta contains, principally, the fertilizing constituents of the food which have failed to be digested or absorbed into the animal system and are, therefore, chiefly in insoluble forms. The urine, on the other hand, contains those fertilizing constituents which have been digested and are largely soluble. The composition of the urine, like that of the solid excreta, varies with the kind and age of the animal, but especially with the nature of food, water drunk, etc., as will be explained later. The composition of the urine of different kinds of farm animals has been found by analysis to be as follows:

Chemical composition of the urine of different animals.

	Water.	Nitrogen.	Phosphoric acid.	Alkalies.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Sheep	86.5	1.4	0.050	2.0
Swine	97.5	0.3	0.125	0.2
Horses	89.0	1.2	....	1.5
Cows	92.0	0.8	....	1.4

The urine of farm animals may be said to be free from phosphoric acid except in case of sheep and swine, where it occurs in minute traces, but is rich in nitrogen and the alkalies (including potash and soda); consequently it is an incomplete manure and should be supplemented by phosphates if used alone. It is best, however, to apply it along with the solid excrement, which contains a considerable amount of phosphoric acid. This latter fact helps to explain why leachings from rotted manure are more valuable as a fertilizer than urine alone. The leachings contain in addition to the constituents of the urine the soluble constituents of the solid manure, among which is a considerable amount of phosphoric acid.

The comparative value of the solid and liquid excrement is shown in the following table:

Composition of solid and liquid excrement of farm animals.

	Water.		Nitrogen.		Phosphoric acid.		Alkalies (potash and soda).	
	Solid.	Liquid.	Solid.	Liquid.	Solid.	Liquid.	Solid.	Liquid.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Horses	76	89.0	0.50	1.20	0.35	Trace.	0.30	1.5
Cows	84	92.0	0.30	0.80	0.25	Trace.	0.10	1.4
Swine	80	97.5	0.60	0.30	0.45	0.125	0.50	0.2
Sheep	58	86.5	0.75	1.40	0.60	0.050	0.30	2.0

The urine is seen to be much richer than the solid dung in every case except that of pigs, in which the high percentage of water (97.5) causes the percentages of the other constituents to fall below those of the same constituents in the solid dung.

The fact that the urine of all farm animals (including pigs) is much richer than the solid excrement is strikingly brought out in the following table, which shows the composition of the dung and urine after the water has been completely removed:

Composition of dry matter of solid and liquid manure.

	Nitrogen.		Phosphoric acid.		Alkalies (potash and soda).	
	Solid.	Liquid.	Solid.	Liquid.	Solid.	Liquid.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Horses	2.08	10.9	1.45	Trace.	1.25	13.6
Cows	1.87	10.0	1.56	Trace.	0.62	17.5
Swine	3.00	12.0	2.25	5.00	2.50	8.0
Sheep	1.78	10.4	1.42	0.37	0.71	14.9

The distribution of the manurial constituents in the urine and dung depends largely on the nature of the food. On this point Warington says:

> If the food is nitrogenous and easily digested the nitrogen in the urine will greatly preponderate; if, on the other hand, the food is imperfectly digested the nitrogen in the solid excrement may form the larger quantity. When poor hay is given to horses the nitrogen in the solid excrement will exceed that contained in the urine. On the other hand corn, [oil] cake, and roots yield a large excess of nitrogen in the urine.

Generally one half and frequently much more of the total nitrogen excreted will be found in the urine, a large portion of the potash, but little or no phosphoric acid or lime. In experiments with sheep at the Maine Experiment Station it was found that "the urine contained nearly half the potash of the total excreta and from half to three fourths of the nitrogen, but no phosphoric acid, the latter being wholly in the solid excrement."

The important points in this connection may be summarized as follows:

(1) Of the nitrogen, phosphoric acid, and potash supplied in the food, comparatively small amounts are assimilated and retained in the animal body, the relation between the amounts of these substances excreted in the urine and the solid excrement depending largely upon the nature of the food.

(2) The urine is much richer in nitrogen than the solid dung. It also contains considerable amounts of potash but is poor in phosphoric acid, which remains almost entirely in the solid excrement. The best results may therefore be expected from applying the mixed solid and liquid excrement.

The figures given in the preceding pages have only approximate and comparative value. They do not admit of too strict an application in practice, because barnyard manure, as can be readily understood, is a very variable substance. Its composition and value depend on a variety of conditions, the more important of which are (1) age and kind of animal, (2) quantity and quality of food, (3) proportion and nature of litter, and (4) method of management of the manure and the length of time it is stored. Each of these factors will be discussed in detail.

INFLUENCE OF AGE AND KIND OF ANIMAL.

The proportions of the potash, phosphoric acid, and nitrogen of the food recovered in the manure vary considerably with the age and kind of animal. Full-grown animals, neither gaining nor losing weight, excrete practically all of the fertilizing constituents consumed in the food. Growing animals and milch cows excrete from 50 to 75 per cent of the fertilizing constituents of the food; fattening or working animals from 90 to 95 per cent.

The variations in the composition of the manure of different classes of animals will be seen from the preceding tables. From these it appears that classified according to strength of equal weights of the normal manure produced the common farm animals stand in the following order: Poultry, sheep, pigs, horses, cows. This difference in value, however, may be largely due to differences in the food commonly fed to the different classes of stock, as will be explained later.

Sheep manure contains a small amount of water and is, weight for weight, the richest manure produced by any of the common farm animals. It is what is called a hot manure, fermenting rapidly with the development of heat. Like horse manure it is especially liable to lose ammonia.

Horse manure is very dry and is therefore difficult to thoroughly mix with litter. It is a hot manure, undergoing fermentation rapidly and generating a high heat on account of its loose texture. It is likely to lose ammonia even more rapidly than sheep manure, and requires careful management—in use of litter, preservatives, etc.—from the moment it is voided. The composition of horse manure is more uniform than that of any other farm animal, chiefly because the food of horses is more uniform. The urine is especially rich.

Pig manure is very variable in composition, due to the variable nature of the food supplied to this animal, but is generally rich although containing a high percentage of water. It generates little heat in decomposing.

The manure of neat cattle, like that of pigs, and for the same reason, is variable in character, but is generally poorer than that of other farm animals on account of its large percentage of water. It decomposes slowly and develops little heat.

Poultry manure is very rich in all the fertilizing elements, but especially so in nitrogen, due to the fact that the urinary secretions, which contain large amounts of nitrogen as well as potash in readily available form, are voided with the solid excrement. It quickly loses nitrogen, however, by fermentation if not properly mixed with absorbents or preservatives.

Warington states that for an equal amount of live weight the sheep produces on the same weight of dry food very much more manure than the pig, while the ox produces even more than the sheep.

It must be borne in mind, therefore, in estimating the manurial value of the dung of different animals that the quantity of dung voided by one animal is much greater than that voided by another. The amount voided by the cow, for example, is much greater than that voided by the horse, so that the inferior value of the former is to some extent compensated for by its greater quantity.

INFLUENCE OF QUALITY AND QUANTITY OF FOOD.

In a given class of animals the value of the manure is determined more by the nature of the food than by any other factor. The quantities of nitrogen, phosphoric acid, and potash in manure stand in direct relation to the quantities of the same ingredients in the food. The crop-producing power of the manure will be largely determined by the nature of the food supplied to the animals producing it. The following table, adapted from a bulletin of the New York Cornell Station, shows the wide variation in manurial value of some of the more common feeding stuffs. (See also table p. 4.)

Fertilizing value of feeding stuffs.

	Value of nitrogen in 1 ton.	Value of phosphoric acid in 1 ton.	Value of potash in 1 ton.	Total fertilizing value per ton.
Corn meal	$4.53	$0.83	$0.31	$5.66
Corn silage	0.78	0.14	0.32	1.24
Crimson clover (green)	1.29	0.16	0.44	1.89
Crimson clover hay	6.63	0.82	2.26	9.71
Red clover hay	5.70	0.54	1.31	7.55
Gluten meal	15.09	0.39	0.05	15.53
Cotton-seed meal	20.85	3.66	1.65	26.16
Linseed meal	16.08	2.28	0.99	19.36
Meat scrap	29.01	6.01	0.67	35.69
Wheat	7.08	0.96	0.45	8.49
Oats	5.36	0.90	0.45	6.70
Skim milk	1.74	0.26	1.08	2.11
Timothy hay	3.00	0.43	1.17	4.60
Wheat bran	7.56	3.40	1.34	12.30
Wheat straw	0.81	0.30	1.02	2.18
Turnips	0.48	0.14	0.34	0.96

As already explained, from 50 to 95 per cent of the fertilizing constituents of food is recovered in the manure, depending upon the kind of animal fed (see p. 10).

In order to find from this table the amount of nitrogen, phosphoric acid, and potash which may be expected in manure, it is necessary simply to subtract from the amount of these constituents contained in the food the amount retained in the animal body. It can be readily seen that as regards the value of the manure produced the concentrated feeding stuffs, such as meat scrap, cotton-seed meal, linseed meal, and wheat bran stand first; the leguminous plants, such as red and crimson clover, etc., second; the cereals (wheat, oats, corn, etc.), third, and root crops last. Thus with full-grown animals neither gaining nor losing weight practically all of the fertilizing constituents of the food are obtained in the manure and each ton of wheat bran, for example, fed would yield manure having a fertilizing value of $12.30, each ton of clover hay $7.50, each ton of oats $6.70, and each ton of turnips 96 cents. With growing animals, milch cows, etc., only about 75 per cent of these amounts, or $9.20, $5.60, $5, and 72 cents, respectively, would be obtained in the manure. Finally, with working and fattening animals, which excrete about 90 per cent of the fertilizing constituents of their food, the corresponding amounts would be $11, $6.75, $6, and 86 cents, respectively.

As the table shows, the amount of nitrogen present in foods is the most important element in determining the value of the manure, since it is the most costly fertilizing constituent and is present in much larger proportion, as a rule, than phosphoric acid and potash. The inorganic substances of foods (potash, phosphoric acid, lime, etc.) pass very largely into the manure; consequently the manure is proportionately richer in these constituents than the food. The case is somewhat different with the nitrogenous substances, which are partly used in the production of meat, tendon, wool, milk, etc., thus leaving the manure in many cases poorer in nitrogen than the food consumed. Those, however, which are not so used undergo modifications in the process of digestion which render their nitrogen more available to plants.

As the New York Cornell Station has shown, increasing the amount of nitrogenous matter in the food increases the secretion of urine, thus necessitating the use of more litter and by this means increasing the bulk of the manure produced. The use of nitrogenous foods thus brings about the same result as the use of watery foods.

INFLUENCE OF THE NATURE AND PROPORTION OF LITTER.

Litter is used to furnish a clean and healthful bed for animals, to absorb and retain liquid excrement, to extend manure and render it easier to handle, to increase the physical and in some cases the chemical action of manure, and to check and control decomposition. The materials generally used are not, as a rule, rich in fertilizing constituents, as the following table of composition given by Warington will show:

Fertilizing constituents in one ton of litter.

	Nitrogen.	Phosphoric acid.	Potash.
	Pounds.	*Pounds.*	*Pounds.*
Dead leaves	16	6	6
Straw	8 to 12	4 to 6	12 to 32
Peat moss	16	Trace.	Trace.
Sawdust	4 to 14	6	14
Spent tan	10 to 20	....	....
Peat	20 to 40	....	....

The use of litter therefore tends to dilute manure rather than improve its chemical composition, but it absorbs and holds the valuable liquid parts and reduces the loss of ammonia.

MANAGEMENT OF MANURE.

We have seen that barnyard manure is a material which rapidly undergoes change. Where it is practical to haul the manure from the stalls and pen and spread it on the field at frequent intervals the losses of valuable constituents need not be very great, but when (as in winter) the manure must be stored for some time the difficulties of preservation become greatly increased.

Under these conditions, deterioration of manure results from two chief causes, (1) Fermentation, whereby a certain amount of the nitrogen is lost, and (2) weathering or leaching, which involves a loss of the soluble fertilizing constituents, including potash and phosphoric acid as well as nitrogen.

FERMENTATION OF MANURE.

The fermentation of manure is due to the action of minute microscopic organisms which belong to two great classes, (1) those which require an abundant supply of air (oxygen) and which die when deprived of oxygen—known as aërobic ferments; and (2) those which grow without oxygen and die when exposed to it—known as anaërobic ferments.

The decomposition observed in the manure heap is due as a rule to the combined action of these two classes of ferments. On the outer surface of the heap, where the air circulates freely, the first class (aërobic) is active,while in the interior of the heap, where the supply of air is limited, the fermentation is due to the anaërobic ferments. The latter soon run their course and cease to exist. Their function seems to be principally to break up the more complex substances of the manure and prepare them for the further action of the aërobic ferments which finally convert them into simpler compounds such as water, carbonic-acid gas, and marsh gas.

Where the manure is compacted (as in deep stalls for instance) the carbonic acid gas formed by fermentation soon permeates the mass so completely as to entirely exclude the air, thus arresting fermentation. In loose heaps into which air is freely admitted fermentation of the aërobic form may go on indefinitely.

The fermentations of manure are very complex and vary according to circumstances. The principal conditions affecting these processes are (1) temperature, (2) supply of air as determined by compactness of heap, (3) moisture, (4) the composition of the manure, and (5) the nature of preservatives added.

The higher the temperature the more rapidly will manure decay. In aërobic fermentation of manure the temperature may rise to 122° to 140°, or even 158° F. On the other hand, in the interior of the heap, where anaërobic fermentation is in progress, the temperature rarely rises above 95° F. Experiments have indicated that 131° F. is the most favorable temperature for manure fermentations.

As already explained, the supply of air determines whether the slow-acting anaërobic ferment or the more vigorous aërobic ferment predominates. The careful regulation of the two kinds of fermentation is necessary to the successful rotting of manure. If the heap is too loosely built the decomposition is too rapid. The materials useful for the formation of humus in the soil are destroyed, and the nitrogen, especially that of the urine, escapes into the air, largely in the form of ammonia. On the other hand, if the manure is too firmly packed the decomposition may be too slow and the manure will not become sufficiently disintegrated to produce the best effect in the soil.

A powerful means of controlling fermentation is the supply of moisture. The addition of water lowers the temperature and thus retards fermentation. By filling up the pores of the mass and excluding the air it checks aërobic fermentation when this becomes too active. French authorities maintain that the principal precautions necessary to prevent losses of ammonia consist simply in regularly and properly watering the manure with the leachings. In case of drought, if the leachings are insufficient, the lack should be made up with water.

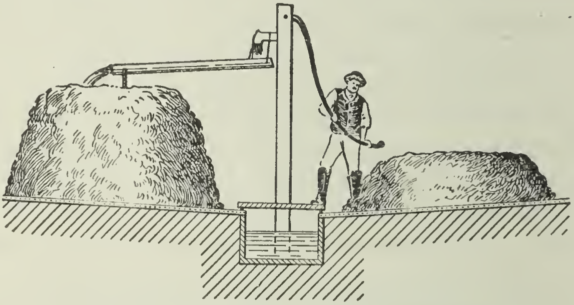

Fig. 2.—The French method of keeping manure.

The need of keeping manure moist is especially marked in case of horse manure, which is naturally dry and decomposes with great rapidity. The same is true in a less degree of sheep manure. The common and harmful "fire-fanging" is the result of an insufficient supply of water and may be readily checked by sprinkling. The sprinkling, however, should be regularly done and the heap kept in a constant state of moisture, otherwise the alternate wetting and drying will result in a loss of ammonia. Preservation of manure in this manner is generally practiced in Europe and the product obtained is highly esteemed as a fertilizer. It is "very dark colored, or even black, and acquires a highly offensive odor, while the straw in it loses its consistency and becomes soft and incoherent." This black substance is held by certain French agriculturists to possess special value as a plant food. A method employed in the preparation of this well-rotted manure in France is as follows: The manure is placed on slightly inclined plats of packed earth or cement, so arranged that the leachings drain out into a pit from which they are pumped up and distributed over the manure heap. It is usual to provide two manure plats so arranged that when one is full (when the manure is 8 to 10 feet high) it may be allowed to ferment undisturbed while the other is used. The manure is carried from the stables to the top of the manure heap in wheelbarrows over an inclined plane of boards. Care is also taken to smooth down the sides of the heap to prevent the too free access of air and the loss of leachings. The system here described is illustrated in fig. 2.

It has been questioned whether the construction of expensive cisterns for collecting the manure leachings repays the cost, but it is obviously desirable from what has been said regarding the value of the liquid manure and the desirability of promoting regular and uniform fermentation of the manure, that the leachings should be saved and added to the manure heap by some means. Stored separately, the liquid part rapidly deteriorates and the solid part, from lack of moisture, is liable to undergo "fire-fanging," or harmful fermentation.

The nature and extent of fermentation in manure also depends to some extent on the composition of the manure, more particularly upon the amount of nitrogen in a soluble form which it contains. The greater the amount of soluble nitrogen the more rapid the fermentation. Urine, as we have already seen, is rich in soluble nitrogenous compounds, and this explains why it decomposes so rapidly.

By fermentation manure decreases rapidly in bulk. The substances of which it is composed are converted largely into water and gases, principally carbonic acid gas, and where fermentation is not properly controlled, nitrogen may escape either in the free gaseous state or as ammonia. The coarse materials of the manure are gradually decomposed and are dissolved to a considerable extent in the black liquid which oozes out of the manure heap. The mineral matter (the phosphates, potash, etc.) is also rendered more soluble. When properly controlled, therefore, fermentation is a valuable means of increasing the availability of the fertilizing constituents of manure, although it decreases the bulk; but when not properly controlled it seriously reduces the value of the manure.

LEACHING OF MANURE.

Leaching is the second cause of deterioration of manure. When manure is exposed to the action of the elements and the leachings allowed to drain away it rapidly decreases in value. Both the organic and the mineral constituents originally present or which have been made soluble by fermentation are carried off and lost. Experiments at the New York Cornell Experiment Station indicated "that horse manure thrown in a loose pile and subjected to the action of the elements will lose nearly one half of its valuable fertilizing constituents in the course of six months; and that mixed horse and cow manure in a compact mass and so placed that all water falling upon it quickly runs through and off is subjected to a considerable, though not so great, a loss."

The Kansas Station concludes from similar observations "that farmyard manure must be hauled to the field in spring, otherwise the loss of manure is sure to be very great, the waste in six months amounting to fully one half of the gross manure and nearly 40 per cent of the nitrogen that it contained."

The following experiments made by Dr. Voelcker in England show very strikingly the loss in weight and of nitrogen in manure stored under different conditions. Mixed manure containing 66.2 per cent of moisture was divided into three 1,000 pound lots. Lot 1 was placed in a heap in the open air, lot 2 in a heap under a shed, and lot 3 was exposed in the open air in a thin layer. The weights of the manure and the amounts of nitrogen it contained at the end of different periods were as follows:

Losses of manure under different methods of storing.

	In heaps under a shed.		Exposed to air in heaps.		Exposed to the air in thin layers.	
	Weight.	Nitrogen.	Weight.	Nitrogen.	Weight.	Nitrogen.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Manure at the beginning of experiment.	1,000	6.43	1,000	6.43	1,000	6.43
Manure after 6 months	495	5.91	714	6.39	865	4.66
Manure after 9 months	398	5.02	703	4.19	612	2.47
Manure after 12 months	379	5.77	700	4.55	575	2.27
Moisture at end of 12 months (per cent).	41.6		74.3		65.6	

The manure stored in a heap under cover lost 14 per cent of its nitrogen in twelve months; exposed in a heap, 30 per cent; and exposed in thin layers, 64 per cent.

Field experiments by Kinnaird with manure kept in an open court and under cover resulted in an increase of about 4 tons of potatoes and 10 bushels of wheat per acre in favor of the covered manure. The comparative value of leached and unleached manure has been carefully tested at the Ohio Station on corn and wheat and mixtures of clover and timothy. The experiments show a wide difference in value between the leached and unleached manure and indicate that the margin of profit from open-yard manure is extremely small.

PRESERVATION OF MANURE.

Having now briefly discussed the nature and extent of the changes which manure is likely to undergo when stored in heaps, let us inquire into the best means of preventing loss of fertilizing value during these changes. It is a well-known fact that certain of the organisms which cause decomposition of manure are voided with the dung and commence their activity at once. In case of horses and sheep these organisms cause a considerable loss of ammonia in a comparatively short time. It is necessary therefore to adopt prompt measures in order to reduce loss from this source to a minimum. The means which are available for this purpose are the use of absorbents and preservatives, such as straw, peat, sawdust, dirt, gypsum (land plaster), kainit, etc. The litter takes up the liquid manure, thus preserving it to some extent from decomposition and also absorbs to a considerable extent the ammonia produced by fermentation and prevents its escape into the air.

The relative absorptive power of various materials commonly used as absorbents in stables is shown in the following table:

Absorptive power of different kinds of litter.

	Water retained by 100 lbs. of material after 24 hours.	Ammonia absorbed by 100 lbs. of dry matter in different materials.
	Pounds.	*Pounds.*
Wheat straw	220	0.170
Partially decomposed oak leaves	162	....
Peat	600	1.103
Sawdust	435	0.046
Spent tan	450	....
Air-dried humus soil	50	0.660
Peat moss	1,300	0.863

It thus appears from the table that peat and peat moss are the best absorbents. It has already been shown (p. 12) that they also furnish the largest amounts of fertilizing constituents. Peaty soil is also an effective absorbent, and the use of a mixture of peaty earth with straw as litter has been strongly recommended. An addition of from 35 to 40 pounds of loam per head daily has been found advantageous, and where straw is scarce it has been replaced to the extent of one fourth or one third by earth. The amount of litter required for any given animal depends largely upon the character of the food. Watery foods and those containing a large amount of nitrogen increase the secretion of urine and so increase the amount of litter necessary to absorb the liquid and keep the animal clean. A safe general rule is that the litter should amount to at least one third of the dry matter of the food consumed. The following amounts per day for different animals are recommended: Sheep, three fifths pound of litter; cattle 9 pounds, and horses, 6½ pounds.

It is not advisable as a rule to use an excess of litter beyond that required to keep the animal clean and absorb the liquid excrement, since the materials available for bedding are as a rule poor in fertilizing constituents, and so extend and dilute the manure unnecessarily.

A small amount of gypsum (land plaster) sprinkled on the moist dung or urine is a popular and effective means of fixing the ammonia.

It should be remembered, however, that unless the gypsum becomes moist it will have little effect. Kainit used in the same way tends to arrest fermentation, but it must be used with caution or it may injure the feet of the animals standing on it. Both kainit and acid phosphate sprinkled on the manure before it is thrown into the heap are valuable as preservatives, and besides increase the value of the manure, increasing the proportion of those constituents (potash and especially phosphoric acid) in which it is somewhat deficient. German investigators who have given a great deal of attention to the subject of preservatives for manure unanimously recommend the use of superphosphate-gypsum, a by-product of the manufacture of superphosphates; but as this product is not found in the American market its place may be taken by the ordinary acid phosphate or superphosphate of the trade used in connection with a small amount of gypsum.

A German authority recommends the use of approximately the following amounts of the different preservatives per day:

Amounts of different preservatives to be used per head daily.

	Per horse, 1,000 pounds weight.		Per cow, 880 pounds weight.		Per pig, 220 pounds weight.	Per sheep, 110 pounds weight.
	Lbs.	*Ozs.*	*Lbs.*	*Ozs.*	*Ounces.*	*Ounces.*
Superphosphate	1	0	1	2	3	$2\frac{1}{2}$
Gypsum	1	9	1	12	$4\frac{3}{5}$	$3\frac{3}{5}$
Kainit	1	2	1	5	4	$3\frac{1}{5}$

If both superphosphate and gypsum are used, the above proportions of these materials should be reduced from one third to one half. Kainit should be applied to the fresh manure and covered with litter so that it does not come in contact with the feet of the animals. Whether it will be good economy to use these materials for this purpose will depend upon their market price in the locality in which it is proposed to employ them.

In cases where different kinds of animals are kept, one of the most effective means of securing moderate and uniform fermentation of the manure heap is to see that the moist "cold" cow and pig manure is intimately mixed with the dry "hot" horse and sheep dung. The former makes the heap more moist and checks the too rapid fermentation and "fire fanging" of the latter.

It will be understood from what has been said that in order to reduce the loss to a minimum, manure heaps should be made compact and kept moist. Under cover the last result is secured by collecting the liquid manure and at frequent intervals sprinkling it over the heap, or when the supply of this is deficient, by sprinkling with water. Where the manure heap is exposed to the rain in pits from which there is no drainage it probably does not require so much attention, but still care must be taken to prevent loss by alternate leaching when heavy rainfalls occur, and drying out in time of drought.

Regarding the management of manure, Prof. Frear, of the Pennsylvania Experiment Station, says:

> To secure such kind and degree of rotting as shall make the manure easily handled and put it into the condition best suited to the crops it is to fertilize, both extremes of moistness and cold, and of exposure and heat, are to be avoided.
>
> It is a much-discussed question whether this mean condition is best obtained in practice by the preservation of the manure in dished yards, subject to more or less exposure to wind and sun, to full exposure to rain, but to more loosely leaching, or under covered sheds where it is protected from sun and rain, and largely from wind. In both cases it is supposed to be compacted fully as the heaps are forming.

Storer expresses a doubt whether sheds built to shelter manure have ever paid their cost. On the other hand, Prof. Roberts, of the New York Cornell Station, recommends the construction of sheds or covered yards for the protection of the manure. The use of completely covered barnyards for protecting manure has in recent years met with much favor in certain parts of the country. The manure from the horse and cattle stables and the sheep and calf pens is spread out evenly over these yards, covered with coarse litter, and the whole kept firmly packed by allowing animals to run over it, thus preventing injurious fermentation. The construction of a cheap and durable covered yard, illustrated in figs. 3, 4, and 5, is thus described by Roberts:

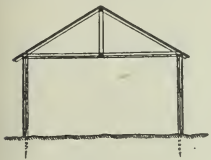

Fig. 3.

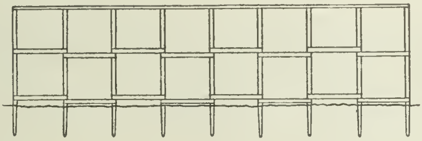

Fig. 4.

Fig. 5.

Plans for a cheap covered barnyard.

> Long posts or poles, 8 inches in diameter at the butt, are set in the ground 2 feet deep and 6 feet apart. Upon these are spiked 2 by 4 scantling, about 4 feet apart, for nailing girts, and a plate 2 by 6 is nailed on top of the posts which have been previously sawed off to a line after the girts have been spiked to them. Round poles flattened at the ends, or 2 by 6 joists doubled, spiked to the heads of the posts, will tie the building together. Ten feet will be quite high enough for the story; and one story will suffice if no straw is to be stored above except that which is placed there to exclude the cold. A few poles or old rails laid on these cross-ties which bind the building together will suffice to sustain the weight of the straw, while the straw will exclude the cold, and absorb the moisture far better than an expensive matched ceiling.
>
> On the inside of the posts which have been set in the ground flattened poles, rails, or slabs, or cheap boards may be nailed horizontally, and the space between the outside vertical boarding and the inside horizontal boarding may be filled with straw. This kind of a wall is far drier and more comfortable for the animals than one made of costly stone or brick.
>
> If it is desired to have a place to store straw, the building should be higher, the joists stronger and more numerous than in the one-story building, and they will all have to be supported by a timber, supported by posts placed under their centers. The roofs should be steep, and can be made of any material which will shed water. When the posts which have been set in the ground have rotted off, or are much decayed, they may be sawed off even with the ground and supported by placing

underneath each one of them a large flat stone. Whenever the building is treated in that way it will be necessary to brace it thoroughly. It might be well in a windy country to brace so wide a building at the start.

Such a building will be inexpensive and reasonably durable. It will serve as a place for depositing manure when needed; it will shelter the animals while they are being watered and the stables are being cleaned and aired, and give facilities for preventing loss of valuable fertilizing material either by leaching or firing.

A more elaborate and expensive style of covered yard, suggested by the American Agriculturist, is shown in fig. 6, which is worth considering when the construction of a barn is contemplated.

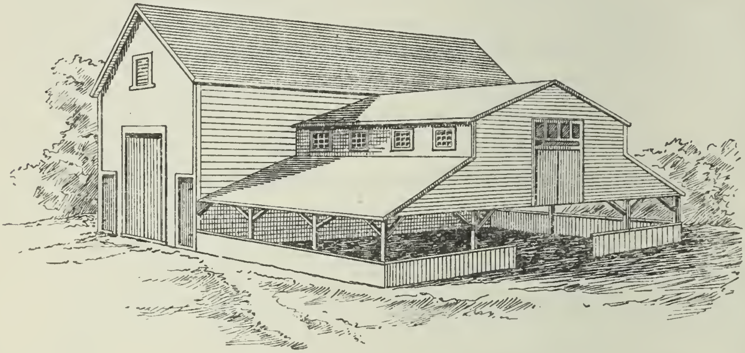

Fig. 6.—A convenient covered barnyard.

This provides not only for the required protection of both animals and manure, but affords also an excellent grain chamber where grain can be stored for convenient use. Under the side roofs is also afforded a chance for the storing of small tools and a great variety of articles that are continually in the way when stored about the farm buildings. It also provides splendid protection to animals when housed at night during the summer, this roof protecting them from heavy showers in the night and affording an excellent opportunity for exercise in the winter, as all the sides, except that toward the south, can be protected against cold winds by being temporarily boarded up.

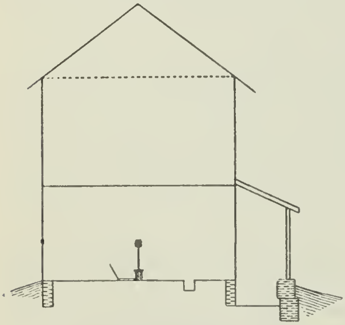

Fig. 7.—A cheap shelter for manure.

Many stables are so situated that by adding a cheap leanto, as shown in fig. 7, "a receptacle for caring for the manure is easily provided. The outside boarding of the leanto should be, for a part of the way at least, put on horizontally and hung in the form of flat doors, so that the manure can be easily loaded on a wagon standing on the outside of the building."

The unsatisfactory results attending the use of manure sheds and covered yards have probably been due to the fact that these structures have generally been loosely constructed, allowing the free circulation of air which has dried out the manure. We have already seen the losses caused by dry fermentation. On this account barn cellars, so common in New England, possess decided advantages as receptacles for manure.

The common practice of allowing swine to "work over" the manure in these cellars is a wise one, since it mixes the manure and keeps it well packed and moist. In fact, if these cellars are provided with impervious bottoms to hold the liquid manure, this system of storing manure is probably the most perfect practiced.

In the method practiced in France, the manure heap is under cover and well compacted. Loam, peaty earth, or similar materials are added to moderate fermentation. The impervious floors on which the heap is placed, as explained on page 15, are so arranged that the leachings may be collected and returned to the heap, thus keeping it moderately moist. To prevent mixing fresh manure with old, two floors are provided, so that the manure on one may ferment undisturbed while the other is used.

The method in which the manure is carried regularly from the stable and placed in shallow pits with impervious bottoms, where it is closely packed by allowing animals to run over it, is practiced to a considerable extent both in this country and in Europe, and, as recent experiments at the Pennsylvania Station indicate, it is probably as safe a method as storing in an open shed where no special precautions are taken to keep the manure moist throughout. The objections to it are that the manure is subjected to extremes of drought and moisture and must suffer injury in consequence unless special precautions are taken to guard against these extremes.

A third method, which originated in Europe and is practiced to some extent in this country, is that in which the soil in the stable is removed to a level below that of the outside and the bottoms tamped or cemented. The manure is allowed to accumulate under the animals until it is hauled to the fields, bedding being used in abundance. The feeding troughs are made adjustable so that they can be raised or lowered as required. The manure becomes highly compacted and is kept in a favorable condition of moisture, so that fermentation proceeds slowly and uniformly. At the same time the manure is completely protected from the action of the weather. As would naturally be expected under the circumstances, the manure obtained is stronger than that allowed to ferment in heaps in the ordinary way. This method is highly regarded where it is practiced and it is claimed that the health of the animals does not suffer.

> It is hard to understand, however [says Storer], how the hoofs of the animals can always escape the diseases that are apt to be caused by certain minute organisms which appear to harbor in fermenting dung, and no man can tell without trial how well the system would answer for dairy farms in this country, i. e., in the warmer parts of it. Doubtless it would serve well enough, however, in the case of fattening cattle.

Whatever the system adopted, the following general rules should be observed in the storage of manure: (1) Spread the manure out uniformly; (2) guard as much as possible against the access of air; (3) keep the manure always moist, but not too wet; (4) protect the heap from sunshine.

USE OF MANURE.

It is the prevailing opinion of chemists as well as practical men that where it is practicable it is best to apply manure and urine to the soil in the freshest possible condition. The fertilizing constituents of well-rotted manure, as already explained, are more quickly available to plants; the manure itself is less bulky, easier to distribute, and affords a good breeding place for organisms which promote nitrification* in the soil; and is less likely to promote rank growth than fresh manure. On the other hand, fresh manure mixed with the soil readily undergoes a fermentation which not only increases the availability of its own fertilizing constituents, but also assists in rendering soluble the hitherto insoluble fertilizing constituents of the soil. In fact, even with special precautions to prevent injurious fermentation under the feet of the animals and in the heap, the greatest return is likely to be gotten from manure applied in the fresh condition.

The form in which manure should be applied (whether fresh or rotted) is determined largely by the soil on which it is to be used. If improvement of the mechanical condition is the main object sought, the best results will be obtained by applying the fresh manure to the heavy clay soils, and the well-rotted manure to the light soils. If, however, the prompt action of the fertilizing constituents of the manure is desired, light soils, in a favorable season, are likely to utilize coarse manure to better advantage than heavy soils. Decomposition takes place slowly in heavy soils and the constituents of the fresh manure become available very slowly. In light soils, on the other hand, unless the season is dry, the conditions are such that the manure decomposes readily, and the fertilizing constituents are probably rendered available as fast as the plant needs them. There is also considerable danger on this class of soils that some of the soluble constituents will be carried away in the drainage if well-rotted manure is applied. For this reason such manure should be applied to light soils shortly before it is likely to be needed by the crop. Small applications at frequent intervals is safe rule to follow on these soils. In general, it may be said that for spring application the more readily available rotted manure is preferable to the fresh unrotted material.

On clay soils it often happens that manure produces no effect whatever during the first year on account of slowness of decomposition, but since the clay possesses very powerful absorptive properties the manure is not lost. The fertilizing constituents are retained in the soil and are finally utilized by the crop. There is therefore no danger in applying to clay soils large quantities of manure a long while in advance of the planting of the crop. During dry seasons the manure may produce little effect, but with a sufficient amount of moisture its action is likely to be considerable. The application to such soils of large quantities of manure improves their physical condition, and by the addition of humus renders more porous those which are too compact.

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*Nitrification is the process by which the highly available nitrates are formed from the less active nitrogen of organic matter, ammonia salts, etc. It is due to the action of minute microscopic organisms which develop only in the presence of air, moisture, and a basic substance such as lime or an alkaline carbonate.

The behavior of calcareous soils toward manure is very variable, depending upon the compactness of the soil. In those which are sufficiently porous decomposition goes on with great rapidity, and the soluble fertilizing constituents formed are partially carried away in the drainage water before they can be taken up by the plants. For this reason, as in case of light soils, the manure should be applied in small amounts and at frequent intervals.

The climate also may have an important bearing on this subject. In a warm, damp climate it is a matter of comparative indifference whether the manure is fresh or well rotted when it is applied, since under these conditions decomposition in the soil will be sufficiently rapid. In a dry, hot season, however, it is well known that excessive applications of undecomposed manure manifest a tendency to "burn out" the soil, and this tendency, as has just been stated, is more marked in light soils than in heavy. In cold climates, where the season is short and the conditions for rapid fermentation in the soil unfavorable, the use of fermented manure is preferable.

Fresh manure has a forcing effect and tends to produce stems and leaves at the expense of fruit and grain. It is therefore better for grasses and forage plants than for cereals.

Direct application of manure, as is well known, seriously injures the quality of tobacco, sugar beets, and potatoes, although mangel-wurzels appear to profit by large applications. For these reasons it is advisable in the case of cereals, tobacco, potatoes, and sugar beets to apply the manure to the previous crop, or, where land is to be planted in the spring, to apply in the fall and allow to decompose during the winter. Sir J. B. Lawes has pointed out, however, that wheat on light soil is benefited by direct applications of manure, and that it is only on heavy soils that it is best to apply it to the preceding crop.

"Manifestly," as Storer remarks, "the rankness of fresh dung and urine could be controlled and utilized by applying the manure in small quantities and supplementing it with artificial fertilizers of kinds appropriate to the crops that are to be grown."

What has been said above regarding the application of fresh manure applies especially to manure containing only small amounts of coarse undecomposed litter. It is not generally advisable to apply very coarse manure before the litter has become at least partially decomposed.

It appears, therefore, that no fixed rules regarding the condition in which manure should be used which will apply to all cases can be laid down. It is a matter which naturally must be left largely to the individual judgment of the farmer, based upon a careful study of the character of the soil and climate and the requirements of the crop to be grown.

METHODS OF APPLYING MANURE

In applying manure to the field three methods are pursued: (1) The manure is placed in larger or smaller heaps over the field and allowed to remain some time before being spread; (2) it is broadcasted and allowed to lie on the surface for some time, or plowed in immediately, and (3) it is applied in the hill or drill with the seed.

The first method is objectionable, because it increases labor of handling and chances of loss by fermentation and leaching, while uniform distribution of the manure is not likely to be secured. The spots on which the heaps stand are strongly manured with the leachings of the manure, while the rest of the field receives the coarse parts of the manure largely deprived of its valuable constituents. Another disadvantage of this method is that proper fermentation is interfered with by the leaching out of the nitrogenous matter and the drying action of the wind. The practice of storing manure in large heaps in the field is subject to some extent to the same objections. If, however, the heap is not allowed to lie too long and is carefully covered with earth the loss may be greatly reduced.

Spreading the manure and allowing it to lie on the surface should be practiced only on level fields where there is no danger from surface washing. It has been claimed that when manure is spread broadcast and allowed to lie on the surface there may be a serious loss of ammonia into the air, but experiments have shown that, in case of properly prepared manure, loss from this cause must be very small. On a leachy soil there may be a loss of soluble constituents in the drainage if the manure is spread a long while before the crop is planted, but in ordinary practice the loss from this source is also likely to be insignificant. In this method of application the fertilizing constituents of the manure are uniformly distributed, the liquid portion being gradually and thoroughly incorporated with the soil particles. One serious disadvantage, however, of the method is that the manure before being plowed in is leached to a large extent of its soluble nitrogenous compounds, which, as we have already observed, are necessary for fermentation; and that for this reason it does not so readily ferment in the soil. It is highly advisable, therefore, in the case of light or sandy soils, not to follow this practice, but to plow the manure in as soon as spread.

As to the depth to which it is advisable to plow the manure in, the general rule should be observed that it should not be so deep as to prevent the access of sufficient moisture and air to insure fermentation and nitrification and to permit of rapid washing down of nitrates to the drain. In very compact soils the depth should not exceed 4 inches. In light soils this depth may be considerably increased, although in such soils there is more danger of loss by drainage than with heavy clay soils.

Application in the hill or drill is useful where the supply of manure is limited and the full immediate effect is desired. For forcing truck crops this method is especially valuable. Well-rotted manure is best suited to this method of application. It has been claimed, however, that manure applied in this way sometimes injures the appearance of root crops, especially potatoes, by increasing the amount of scab.

The so-called parking system, or feeding animals on the land, is a method of application which has many advantages; but the distribution of the manure by this system is irregular, and if practiced in autumn or winter the manure is subject to loss by drainage.

The application of liquid manure has certain obvious advantages, and is largely practiced, especially in Europe. Manure leachings is a quick-acting, forcing manure, and is especially valuable for grass. The expense of cisterns for collecting the leachings and the trouble of hauling and distributing, together with the care which must be exercised to prevent loss of nitrogen from the readily fermentable liquid when it stands for any length of time, render it doubtful whether this method is practicable except for special purposes and under peculiar conditions.

RATE OF APPLICATION.

As to the rate at which manure should be applied no fixed rules can be given. The rate will depend upon the character of the soil, the quality of the manure, the nature of the crop, and the frequency of application. Cold moist soils should be manured lightly and often. Thaer, a German writer, states 17 to 18 tons per acre to be an abundant application, 14 tons good, and 8 to 9 light; other German writers consider 7 to 10 tons light, 12 to 18 tons usual, 20 tons or more heavy, and 30 tons very heavy. Stephens suggests 8 to 12 tons for roots and 15 to 20 tons supplemented by commercial fertilizers for potatoes. Sir Henry Gilbert considers 14 tons per acre annually excessive for wheat and barley. In New England the rate varies from 6 to 12 tons. Twenty tons is a frequent application in New Jersey, as well as in other regions where truck farming is practiced. As a general rule it is more scientific to apply small amounts of manure frequently than to apply large amounts at longer intervals.

COMBINING BARNYARD MANURE WITH OTHER FERTILIZING MATERIALS.

It has been the general experience that probably the best way to utilize barnyard manure is in combination with such materials as supplement and conserve its fertilizing constituents. It has already been pointed out how certain substances, such as kainit and superphosphate, which possess a high fertilizing value, may also be used to advantage as preservatives on account of their ability to check fermentation or to fix ammonia. Even the limited extent to which it is necessary to use these materials in the stable will improve the fertilizing value of the manure, but it is necessary to do more than this if a well-balanced fertilizer is desired, for, as has been shown, barnyard manure considered simply as a supplier of nitrogen, phosphoric acid, and potash is comparatively poor. It has been shown that the proportions of potash and phosphoric acid especially are low. The potash, however, is in a very available form and does not need to be reënforced to the same extent as the much less available phosphoric acid.

Although nitrogen is the constituent most abundant in manure it has been found that in order to get the best results in general it should be reënforced if prompt action is desired. This is explained by the fact that a large part of the nitrogen of manure is very slowly available. Sir Henry Gilbert says on this point:

> The nitrogen of farmyard manure must obviously exist in very different conditions. That due to the urine of animals will be most rapidly available, that in the finely divided matter in the feces will be much more slowly available, and that in the litter still more slowly available. Hence, the small proportion that is at once effective and the very large amount that accumulates within the soil in a very slowly available condition.

Experiments at Rothamsted indicate that the nitrogen of barnyard manure is not half as valuable, weight for weight, as that of sulphate of ammonia.

What has been said about supplementing barnyard manure with more concentrated fertilizing materials should not be taken to imply that the two kinds of fertilizers should necessarily be composted or applied at the same time. It may be desirable to apply the manure at intervals of several years, while the concentrated fertilizers would need to be applied annually. However this may be, the facts above given should be borne in mind in applying the supplementary fertilizers.

Whether the farmer can afford to incur the necessary labor and expense involved in the preparation of composts is a question on which there is considerable difference of opinion. This is a matter which must be determined largely by individual needs and conditions, but undoubtedly the manure heap may be utilized to advantage for such purposes as reducing bones and other waste products of the farm and for "killing" cotton seed before it is applied to the soil.

In preparing composts the following directions should be observed: Select a level spot under shelter and convenient to the stables. Remove the earth so as to give a gentle slope from the sides toward the center. It is advisable to tamp the floor of this pit firmly or cover it with puddled clay to prevent loss of leachings. It is also well to have a small drain leading from the center to the side and emptying into a half barrel sunk in the earth. By this means the valuable leachings may be collected and bailed out and sprinkled over the heap, thus assisting materially in promoting a moderate and uniform fermentation of the manure. It is not necessary, however, to provide for this collecting of the leachings if in the construction of the heap the precaution is taken to lay down first a fairly thick layer of the absorbent materials, such as barnyard manure, peat, etc., which it is intended to use. Put down first a layer of these materials then follow with a layer of acid phosphate, for instance, and so on until all the materials are used, wetting each layer thoroughly first with water or urine if it is at hand, and finally with kainit, or other chemicals used dissolved in water. It is well to have at hand a mixture of peaty earth and plaster with which the finished heap is covered to a depth of about 1 inch. The heap should be examined from time to time and moistened with manure leachings, urine, or water if there appears to be any danger of overheating. In from four to six weeks the compost is ready to be forked over, thoroughly mixed, and carried to the field.

The following formulas for composts in which barnyard manure is one constituent have been recommended and in many cases have been tried with favorable results.

Formulas for cotton.

	No. 1.*	No. 2.	No. 3.	No. 4.	No. 5.†	No. 6.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Stable manure	750	750	400	300	300	1,000
Cotton seed	750	750	600	600	600	1,000
Acid phosphate	333⅓	500	800	750		1,000
Floats					750	
Kainit	166⅔		200	350	350	
Rate per acre	1,600	1,600	1,600	1,600	1,600	

* Furman's formula.

†Found especially effective in experiments on cotton.

Formulas for cotton and corn.

	No.7.*	No. 8.	No. 9.	No. 10.	No. 11.	No. 12.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Stable manure	800	500	600	600		600
Stable manure with yard scrapings					1,000	
Cotton seed	750		400			
Cotton-seed meal or fish scrap				700		
Acid phosphate			800	600		
Acid phosphate or bone meal					800	600
Dissolved bone	450	500				
Sulphate of ammonia		150				
Kainit			200	100	200	
Sulphate of potash		150				
Unburnt marl		500				
Salt		200				
Ashes						200
Rich earth or yard scrapings						600
Rate per acre	300-500	300-500				

*When applied to corn on worn soil should be supplemented by 75 pounds of muriate of potash per acre; when used on wheat by 50 pounds of sulphate of potash and by 100 pounds of nitrate of soda sown broadcast in the spring.

Formulas for winter wheat, rye, corn, and cotton.

	No. 13.	No. 14.
	Pounds.	*Pounds.*
Barnyard manure	700	700
Cotton seed	800	
Castor pomace		700
Dissolved boneblack		600
Dissolved bone meal	500	
Rate per acre	500–800	500–800

Formulas for wheat, oats, or rye.

	No. 15.	No. 16.	No. 17.	No. 18.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Stable manure		800	600	600
Stable manure or any rich earth or mold	600			
Cotton seed	600			
Cotton-seed meal				700
Kainit	200			
Muriate of potash		100	100	100
Acid phosphate	600	1, 000		600
Acid phosphate or bone meal			600	
Sulphate of ammonia		100	100	
Dry muck or other rich earth			600	

Formulas for tobacco.

	No. 19.	No. 20.
	Pounds.	*Pounds.*
Stable manure	900	
Fine horse or cow manure, rich mold, or similar material		900
Acid phosphate	500	
Acid phosphate or dissolved bone		600
Fish scrap or tankage		350
Sulphate of ammonia	100	
Sulphate of potash	300	150
Sulphate of magnesia	100	
Plaster (gypsum)	100	

The following dry mixture is recommended by the North Carolina Station for cotton and corn:

	Pounds.
Acid phosphate	800
Muriate of potash	100
Sulphate of ammonia	60
Finely pulverized manure from henhouses, horse or cow stables	1, 040
	2, 000

In experiments on tomatoes, sweet potatoes, and peaches, annual applications of 10 tons per acre of barnyard manure, supplemented by 160 pounds of dissolved boneblack, 80 pounds of muriate of potash or sulphate of potash, and 100 pounds of nitrate of soda, applied separately; and 20 tons of manure, with double the amounts of the other materials, have given good results.

The fermenting of peat with stable manure was formerly practiced to a considerable extent. Where such a compost is desired the materials should be laid down in alternate layers in the proportion of about five parts of peat to one of manure.

LASTING OR CUMULATIVE EFFECT OF BARNYARD MANURE.

Barnyard manure is probably the most efficient means at the disposal of the farmer to permanently improve his soil. No other fertilizer possesses to so great a degree the power of restoring worn soils to productiveness and giving them lasting fertility. It accomplishes this result, however, not so much by the actual fertilizing constituents which it supplies as by improving the physical properties of the soil, increasing the amount of humus, which is generally deficient in worn soils, improving its texture, and increasing its water-absorbing and water-holding power. Experiments have shown that the influence of manure may be perceptible twenty years after application. Observations at Rothamsted, England, during forty years on barley unmanured, manured continuously, and manured during the first twenty years only showed that "there was gradual exhaustion and reduction of produce without manure, and gradual accumulation and increase of produce with the annual application of farmyard manure. But when the application was stopped, although the effect of the residue from the previous applications was very marked, it somewhat rapidly diminished, notwithstanding that calculation showed an enormous accumulation of nitrogen as well as other constituents."

The yield, however, was maintained for twenty years considerably higher than that on the unmanured soil. Continuous manuring of wheat at the rate of 14 tons per acre annually for forty years resulted in an average increase of yield from year to year of one-fourth bushel per acre, or a total of about 10 bushels in forty years. While it is true that there is a constant increase in the productiveness of soil on which barnyard manure is applied regularly, it is not as great as the amounts applied would seem to justify. This is chiefly due to the fact, already explained, that the nitrogen is largely converted into slowly available forms.

SUMMARY.

(1) Barnyard manure is the most important manurial resource of the farm and should be carefully saved and used. It represents fertility drawn from the soil and must be returned to it if productiveness is to be maintained. In many cases it has been demonstrated that the value of the manure obtained in cattle feeding represents largely, if not entirely, the profit of feeding.

(2) There are sound scientific reasons for the high esteem in which this manure is held. It contains all the fertilizing elements required by plants in forms that insure plentiful crops and permanent fertility to the soil. It not only enriches the soil with the nitrogen, phosphoric acid, and potash which it contains, but it also renders the stored-up materials of the soil more available, improves the mechanical condition of the soil, makes it warmer, and enables it to retain more moisture or to draw it up from below.

(3) The amount and value of manure produced by different kinds of farm animals may be judged from the following figures, calculated to 1,000 pounds of live weight: Sheep, 34.1 pounds of manure per day, worth 7.2 cents; calves, 67.8 pounds, worth 6.7 cents; pigs, 83.6 pounds, worth 16.7 cents; cows, 74.1 pounds, worth 8 cents, and horses 48.8 pounds, worth 7.6 cents, basing calculations of value on market prices of commercial fertilizers, which probably gives results much too high. Making liberal allowances for these and other considerations, Prof. Roberts estimates that the value of the manure produced on a small farm carrying 4 horses, 20 cows, 50 sheep, and 10 pigs during the seven winter months amounts to about $250.

(4) The urine is by far the most valuable part of the excreta of animals. It is especially rich in readily available nitrogen, which rapidly escapes into the air if special precautions are not taken to prevent its loss. It is also rich in potash, but deficient in phosphoric acid. It should, as a rule, be used in connection with the solid dung, the one thus supplying the deficiences of the other and making a more evenly balanced manure.

(5) Barnyard manure is a very variable substance. The more important conditions which determine its composition and value are (1) age and kind of animal, (2) quantity and quality of food, (3) proportion of litter, and (4) method of management and age. Mixed barnyard manure properly cared for may be assumed to have the following composition: Water, 75 per cent; nitrogen, 0.57 per cent; phosphoric acid, 0.3 per cent; potash, 0.57 per cent.

(6) Mature animals, neither gaining nor losing weight, excrete practically all the fertilizing constituents consumed in the food. Growing animals and milch cows excrete from 50 to 75 per cent of the fertilizing constituents of the food; fattening or working animals from 90 to 95 per cent. As regards the fertilizing value of equal weights of manure in its normal condition, farm animals probably stand in the following order: Poultry, sheep, pigs, horses, cows.

(7) In a given class of animals the value of the manure is determined more by the nature of the food than by any other factor. The amounts of fertilizing constituents in the manure stand in direct relation to those in the food. As regards the value of manure produced the concentrated feeding stuffs, such as meat scrap, cotton-seed meal, linseed meal, and wheat bran stand first, the leguminous plants (clover, peas, etc.) second, the grasses third, cereals (oats, corn, etc.) fourth, and root crops, such as turnips, beets, and mangel-wurzels last.

The nitrogen of the food exerts a greater influence on the quality of the manure than any other constituent. It is the most costly fertilizing constituent, and is present in largest quantity. It undergoes more modification in the animal stomach than the mineral constituents (potash and phosphoric acid), and rapidly escapes from the manure in fermentation. The secretion of urine increases with the increase of nitrogenous substances in the food, thus necessitating the use of larger amounts of litter and affecting both the amount and value of the manure. The use of watery foods, as is obvious, produces the same result.

(8) The deterioration of manure results from two chief causes, (*a*) fermentation, whereby nitrogen, either as ammonia or in the gaseous state, is set free, and (*b*) weathering or leaching, which involves a loss of the soluble fertilizing constituents. The loss from destructive fermentation may be almost entirely prevented by the use of proper absorbents and preservatives, such as gypsum, superphosphate, and kainit, and by keeping the manure moist and compact. Loss from leaching may be prevented by storage under cover or in pits. Extremes of moisture and temperature are to be avoided, and uniform and moderate fermentation is the object to be sought. To this end it is advisable to mix the manure from the different animals thoroughly in the heap.

(9) When practicable it is best to apply manure in the fresh condition. The disposition to be made of the manure of the farm (both fermented and unfermented) must be determined largely by the nature of the crop and soil. Where improvement of the mechanical condition of the soil is the principal object sought, fresh manure is best adapted for this purpose to heavy soils and well-rotted manure to light soils. Where prompt action of the fertilizing constituents is desired, the best results will probably be obtained by applying fresh manure to the light soils, although excessive applications in this case should be avoided on account of the danger of "burning out" of the soil in dry seasons. Fresh manure has a forcing effect, and is better suited to grasses and forage plants than to plants grown for seed, such as cereals. Direct applications to root crops, such as sugar beets, potatoes, or tobacco, often prove injurious. The manure should be spread when carried to the field, and not left in heaps to leach.

The rate of application must be determined by individual circumstances. As a rule it is better to manure lightly and frequently than to apply a large amount at longer intervals.

(10) One of the best ways to utilize barnyard manure is to combine it with such materials as supplement and conserve its fertilizing constituents. The best results are likely to be obtained by using commercial fertilizing materials in connection with barnyard manure, either in compost or separately. As is well known, barnyard manure is lasting in its effects, and in many cases need not be applied so frequently as the more soluble and quick-acting superphosphates, potash and nitrogen salts, etc.

FARMERS' BULLETINS.

The following is a list of the Farmers' Bulletins available for distribution, showing the number, title, and size in pages of each. Copies will be sent to any address on application to Senators, Representatives, and Delegates in Congress, or to the Secretary of Agriculture, Washington, D. C.:

16. Leguminous Plants. Pp. 24.
19. [Superseded by No. 127.]
21. Barnyard Manure. Pp. 32.
22. The Feeding of Farm Animals. Pp. 32.
23. [Superseded by No. 142.]
24. Hog Cholera and Swine Plague. Pp. 16.
25. Peanuts: Culture and Uses. Pp. 24.
26. [Superseded by No. 129.]
27. Flax for Seed and Fiber. Pp. 16.
28. Weeds: And How to Kill Them. Pp. 32.
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125. Protection of Food Products from Injurious Temperatures. Pp. 26.
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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 22.

THE FEEDING OF FARM ANIMALS.

[REVISED EDITION.]

BY

E. W. ALLEN, Ph. D.,
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., October 19, 1901.

Sir: I have the honor to transmit herewith revised copy for Farmers' Bulletin No. 22, on the Feeding of Farm Animals, prepared under my direction by E. W. Allen, Ph. D., assistant director of this Office. In this article the attempt has been made to make a clear and concise explanation of the principles on which the successful feeding of farm animals is based. These principles have been established by feeding experiments and other investigations at experiment stations and similar institutions in Europe and America, combined with observations of the practice of successful feeders. The present bulletin has been confined to a statement of the general principles of feeding, with the expectation that hereafter it may be possible to discuss the application of these principles to different kinds of farm animals in other publications of this series.

In this second revision of the bulletin certain changes have been made on the basis of more recent information.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

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THE FEEDING OF FARM ANIMALS.

PRINCIPLES OF FEEDING.

The feeding of farm animals, like the use of fertilizers for crops, rests upon quite well-defined general principles. Our knowledge of these principles has been derived from the studies of the chemist and the animal physiologist, on the composition and functions of food and the way it is utilized after it is eaten. These studies have shown that the materials of the body are continually breaking down and being consumed, and that to keep the animal in a healthy and vigorous condition there must be a constant supply of new material. If this is lacking, or is insufficient, hunger and finally death result. To keep up this supply is one of the chief functions of food, but in addition to this the food maintains the heat of the body and at the same time furnishes the force or energy which enables the animal to move the muscles and do work, and also to perform the necessary functions of the body. In furnishing heat and energy the food may be said to serve as fuel. If, in addition to repairing the wastes of the system and furnishing it with heat and energy, growth is to be made (as in the case of immature animals) or milk secreted, an additional supply of food is required. To supply food in the right proportion to meet the various requirements of the animal, without a waste of food nutrients, constitutes scientific feeding. It is by carefully studying the composition of feeding stuffs, the proportion in which they are digested by different animals and under different conditions, and the requirement of animals for the various food nutrients when at rest, at work, giving milk, producing wool, mutton, beef, pork, etc., that the principles of feeding have been worked out. In applying these principles in practice the cost and special adaptations of different feeding stuffs must of course be taken into account.

COMPOSITION OF THE ANIMAL BODY.

The animal body is made up mainly of four classes of substances—water, ash or mineral ingredients, fat, and nitrogenous matters. The proportion in which these four classes of substances occur depends upon the age of the animal, treatment, purpose for which it is kept, etc.

Water constitutes from 40 to 60 per cent of the body, and is an essential part. From 2 to 5 per cent of the weight of the body is ash. This occurs mainly in the bones. The fat varies greatly with the condition of the animal, but seldom falls below 6 per cent or rises above 30 per cent. The nitrogenous material or protein includes all of the materials containing nitrogen; all those outside this group are nitrogen-free, or nonnitrogenous. The nitrogen referred to here is the same as that mentioned in connection with fertilizers, and is the element which constitutes about four-fifths of the atmosphere. It occurs in plants and animals in various compounds grouped under the general name of protein. Lean meat, white of the egg, and casein of milk (curd) are familiar forms of protein. The flesh, skin, bones, muscles, internal organs, brain, and nerves—in short, all of the working machinery of the body—are composed very largely of protein. The albuminoids are a class of compounds included under protein.

COMPOSITION OF FEEDING STUFFS.

The food of herbivorous animals contains the same four groups of substances found in the body, viz, water, ash, protein (nitrogenous materials), and fat; and in addition to these a class of materials called carbohydrates, defined below.

Water.—However dry a feeding stuff may appear to be—whether hay, coarse fodder, grain, or meal—it always contains a considerable amount of water which can be driven out by heat. The amount may be only from 8 to 15 pounds per 100 pounds of material, as in hay, straw, or grain, but in green corn fodder and silage it amounts to nearly 80 pounds, and in some roots to 90 pounds. This water, although it may add to the palatability of a food, is of no more benefit to the animal than water which it drinks. For this reason, and because the proportion of water varies widely, comparisons of different kinds of foods are usually made on a dry or water-free basis, which shows the percentage of food ingredients in the dry matter.

Ash is what is left when the combustible part of a feeding stuff is burned away. It consists chiefly of lime, magnesia, potash, soda, iron, chlorin, and carbonic, sulphuric, and phosphoric acids, and is used largely in making bones. From the ash constituents of the food the digestive organs of the animal select those which the animal needs and the rest is voided in the manure. As a general rule rations composed of a variety of nutritious foods contain sufficient ash to supply the requirements of the body. Corn, however, is poor in ash, and when fed extensively to growing animals, like pigs, it may be necessary to add to it some ash material, as wood ashes, charcoal, or bone meal.

Fat, or the material which in analysis is dissolved from a feeding stuff by ether, includes, besides real fats, wax, the green coloring matter of plants, etc. For this reason the ether extract is usually designated *crude* fat. The fat of food is either stored up in the body as fat or burned to furnish heat and energy.

Carbohydrates are usually divided into two groups: (1) Nitrogen-free extract, including starch, sugar, gums, and the like; and (2) cellulose or fiber, the essential constituent of the walls of vegetable cells. Cotton fiber and wood pulp are nearly pure cellulose. Coarse fodders, like hay and straw, contain a large proportion of fiber, while most grains contain little fiber, but are rich in starch, sugar, etc. (nitrogen-free extract). The carbohydrates form the largest part of all vegetable foods. They are not permanently stored up as such in the animal body, but are either stored up as fat or burned in the system to produce heat and energy. They are one of the principal sources of animal fat.

Protein (or nitrogenous materials) is the name of a group of materials containing nitrogen. All other constituents of the feeding stuffs—the ash, fat, and carbohydrates—are nonnitrogenous or free from nitrogen. Protein materials are often designated as "flesh formers," because they furnish the materials for the lean flesh; but they also enter largely into the composition of blood, skin, muscles, tendons, nerves, hair, horns, wool, the casein and albumen of milk, etc. For the formation of these materials protein is absolutely indispensable. No substances free from nitrogen can be worked over into protein or fill the place of protein. It is, then, absolutely necessary for an animal to be provided with a certain amount of protein in order to grow or maintain existence. Under certain conditions it is believed protein may be a source of fat in the body; and finally it may be burned, like the carbohydrates and fat, yielding heat and energy.

SOURCES OF HEAT AND ENERGY.

The sources of heat and energy in the animal, then, are the protein, fat, and carbohydrates of the food, and the fat and protein of the body, for the fat and protein of the body may be burned like that in the food. The value of the fat for producing heat is nearly two and a half times that of carbohydrates or protein. The sources of fat in the body are the fat, carbohydrates, and, probably, the protein of the food; and the exclusive source of protein in the body is the protein in the food. These groups of food materials are termed nutrients.

SOURCES OF FAT.

To a certain extent at least the nutrients may replace one another, although, as stated above, no other nutrient can take the place of protein for building tissue and repairing waste of nitrogenous materials in the body. The fat and carbohydrates perform similar functions, and to a large extent carbohydrate materials may replace fat in the food, even when a large fat production is demanded of the animal, as in the case of the cow. For example, Jordan, at the New York State experiment station, fed a cow for ninety-five days upon food from which the fat had been extracted as thoroughly as possible. In spite of this absence of food fat the cow continued to secrete milk similar to that produced on a normal ration. Nearly 63 pounds of fat was yielded in the milk during the ninety-five days, and the cow gained 47 pounds during that time, being judged a much fatter cow at the end than at the beginning. He concludes that the milk fat was produced quite largely, if not entirely, from the carbohydrates of the food.

The exact processes by which the nutrients are changed into the different components or products of the body is not definitely known.

TABLE OF COMPOSITION.

The composition of feeding stuffs, or the proportion in which the nutrients occur, is determined by chemical analysis. A large number of analyses of American feeding stuffs have been made. These analyses have been compiled, and are summarized in the table given at the end of this bulletin. This table shows the average composition of a large number of feeding stuffs in common use, together with the limits within which the composition has been found to vary. These maximum, minimum, and average results are given for the foods as they are fed (green or dry). The carbohydrates have here been divided into the two groups mentioned above, viz, fiber and nitrogen-free extract, as they are determined separately. The sum of the two gives the total carbohydrates. In the last column of this table is stated the total number of analyses from which the average was obtained. The probable accuracy of the average increases with the number of analyses on which it is based.

This table shows how great are the differences in composition between different kinds of feeding stuffs. Take the case of protein for instance. In straw this varies from 3 to 4 per cent; in hay of grasses from 6 to 8 per cent; in hay of clovers, cowpeas and the like, from 12 to 16 per cent; in grains from 10 to 12½ per cent; and in by-products it reaches 35 per cent in linseed meal, 42 per cent in cottonseed meal, and 47½ per cent in peanut meal. Protein, like its counterpart, the nitrogen in fertilizers, is the most expensive element, and a considerable amount of it is absolutely essential to growth. The table will aid in the selection of the cheapest sources of food materials.

DIGESTIBILITY OF FEEDING STUFFS.

The table just referred to gives the total amounts of nutrients found by analysis in different feeding stuffs. But only a portion of these amounts is of direct use to the animal, i. e., only that digested. A part of the food is dissolved and otherwise altered by the juices of the mouth, stomach, and intestines, absorbed from the alimentary canal, and in the form of chyle passes into the blood and finally serves to nourish and sustain the body. This portion is said to be digested and assimilated, and from it alone the animal is nourished. The other portion, the part not digested, passes on through the body and is excreted as manure.

PERCENTAGE OF NUTRIENTS DIGESTED.

As the rates of digestibility are not constant for different foods, and as only the digestible portion is of any nutritive use to the animal, it is essential to know in the case of each feeding stuff what part of its protein, fat, and carbohydrates (the total quantity of which is shown by analysis) is actually digested by the animal. This is determined by digestion experiments with animals, and to secure approximately accurate figures the trials are repeated with a large number of animals and under various conditions. The figures obtained represent the percentages of the nutrients digested and are called digestion coefficients.

In the case of clover hay, for instance, on an average 60 per cent of the protein which it contains, 55 per cent of the fat, 55 per cent of the fiber, and 65 per cent of the nitrogen-free extract are digested by cows. The table of composition shows red-clover hay to average 12.3 per cent of protein, or 12.3 pounds of protein in 100 pounds of hay. As only 60 per cent of this is digestible, 100 pounds of hay would contain only 7.38 pounds of digestible protein. The remaining 4.92 pounds of protein are voided and do not aid in nourishing the animal. The amounts of digestible fat and carbohydrates (fiber and nitrogen-free extract) are calculated in a similar way. The digestibility of such coarse fodders as straw, coarse hay, etc., is relatively low. The digestibility, like the composition, varies somewhat for the same kind of feeding stuff grown under different conditions and fed to different animals.

AMOUNTS OF DIGESTIBLE NUTRIENTS IN DIFFERENT FEEDING STUFFS.

To simplify matters for the feeder, calculations have been made of the amounts of digestible protein, fat, and carbohydrates contained in 100 pounds each of a large number of more commonly used feeding stuffs. As has been fully explained above, they are derived from averages of composition and of digestibility, both of which are subject to considerable variation. In calculating them American analyses and digestion coefficents found in American experiments were used as far as possible. They are the figures which the farmer has to consult to find the approximate food value of a material in selecting his feeding stuffs or making up a ration.

Dry matter and digestible food ingredients in 100 pounds of feeding stuffs.

Feeding stuff.	Total dry matter.	Protein.	Carbohydrates.	Fat.	Fuel value.
Green fodder:	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Calories.*
Corn fodder[1] (average of all varieties)	20.7	1.10	12.08	0.37	26,076
Kafir-corn fodder	27.0	0.87	13.80	0.43	29,101
Rye fodder	23.4	2.05	14.11	0.44	31,914
Oat fodder	37.8	2.44	17.99	0.97	42,093
Redtop, in bloom	34.7	2.06	21.24	0.58	45,785
Orchard grass, in bloom	27.0	1.91	15.91	0.58	35,593
Meadow fescue, in bloom	30.1	1.49	16.78	0.42	35,755
Timothy,[2] at different stages	38.4	2.01	21.22	0.64	45,909
Kentucky blue grass	34.9	2.66	17.78	0.69	40,930
Hungarian grass	28.9	1.92	15.63	0.36	34,162
Red clover, at different stages	29.2	3.07	14.82	0.69	36,187
Crimson clover	19.3	2.16	9.31	0.44	23,191
Alfalfa,[3] at different stages	28.2	3.89	11.20	0.41	29,798
Cowpea	16.4	1.68	8.08	0.25	19,209
Soy bean	28.5	2.79	11.82	0.63	29,833
Rape	14.3	2.16	8.65	0.32	21,457
Corn silage (recent analyses)	25.6	1.21	14.56	0.88	33,046
Corn fodder,[1] field cured	57.8	2.34	32.34	1.15	69,358
Corn stover, field cured	59.5	1.98	33.16	0.57	67,766
Kafir-corn stover, field cured	80.8	1.82	41.42	0.98	84,562
Hay from—					
Barley	89.4	5.11	35.94	1.55	82,894
Oats	84.0	4.07	33.35	1.67	76,649
Orchard grass	90.1	4.78	41.99	1.40	92,900
Redtop	91.1	4.82	46.83	0.95	100,078
Timothy[2] (all analyses)	86.8	2.89	43.72	1.43	92,729
Kentucky blue grass	78.8	4.76	37.46	1.99	86,927
Hungarian grass	92.3	4.50	51.67	1.34	110,131
Meadow fescue	80.0	4.20	43.34	1.73	95,725
Mixed grasses	87.1	4.22	43.26	1.33	93,925
Rowen (mixed)	83.4	7.19	41.20	1.43	96,040
Mixed grasses and clover	87.1	6.16	42.71	1.46	97,059
Red clover	84.7	7.38	38.15	1.81	92,324
Alsike clover	90.3	8.15	41.70	1.36	98,460
White clover	90.3	11.46	41.82	1.48	105,346
Crimson clover	91.4	10.49	38.13	1.29	95,877
Alfalfa[3]	91.6	10.58	37.33	1.38	94,936
Cowpea	89.3	10.79	38.40	1.51	97,865
Soy bean	88.7	10.78	38.72	1.54	98,569
Wheat straw	90.4	0.37	36.30	0.40	69,894
Rye straw	92.9	0.63	40.58	0.38	78,254
Oat straw	90.8	1.20	38.64	0.76	77,310
Soy-bean straw	89.9	2.30	39.98	1.03	82,987
Roots and tubers:					
Potatoes	21.1	1.36	16.43	....	33,089
Beets	13.0	1.21	8.84	0.05	18,904
Mangel-wurzels	9.1	1.03	5.65	0.11	12,889
Turnips	9.5	0.81	6.46	0.11	13,986
Ruta-bagas	11.4	0.88	7.74	0.11	16,497
Carrots	11.4	0.81	7.83	0.22	16,999
Grains and other seeds:					
Corn (average of dent and flint)	81.1	7.14	66.12	4.97	157,237
Kafir corn	87.5	5.78	53.58	1.33	116,022
Barley	89.1	8.69	64.83	1.60	143,499
Oats	89.0	9.25	48.34	4.18	124,757
Rye	88.4	9.12	69.73	1.36	152,400
Wheat (all varieties)	89.5	10.23	69.21	1.68	154,848
Cotton seed (whole)	89.7	11.08	33.13	18.44	160,047
Mill products:					
Corn meal	85.0	6.26	65.26	3.50	147,797
Corn-and-cob meal	84.9	4.76	60.06	2.94	132,972
Oatmeal	92.1	11.53	52.06	5.93	143,302
Barley meal	88.1	7.36	62.88	1.96	138,918
Ground corn and oats, equal parts	88.1	7.01	61.20	3.87	143,202
Pea meal	89.5	16.77	51.78	0.65	130,246
Waste products:					
Gluten meal—					
Buffalo	91.8	21.56	43.02	11.87	170,210
Chicago	90.5	33.09	39.96	4.75	155,918
Hammond	91.9	24.90	45.72	10.16	174,228
King	92.8	30.10	35.10	15.67	187,399
Cream gluten (recent analyses)	90.4	30.45	45.36	2.47	151,420
Gluten feed (recent analyses)	91.9	19.95	54.22	5.35	160,533
Buffalo (recent analyses)	91.0	22.88	51.71	2.89	150,933
Rockford (Diamond)	91.3	20.38	54.71	3.82	155,788
Hominy chops	88.9	8.43	61.01	7.06	158,952
Malt sprouts	89.8	18.72	43.50	1.16	120,624

[1] Corn fodder is entire plant, usually sown thick.

[2] Herd's grass of New England and New York.

[3] Lucern.

Dry matter and digestible food ingredients in 100 pounds of feeding stuffs—Continued.

Feeding stuff.	Total dry matter.	Protein.	Carbohydrates.	Fat.	Fuel value.
Waste products—Continued.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Calories.*
Brewers' grains (wet)	24.3	4.00	9.37	1.38	30,692
Brewers' grains (dried)	92.0	19.04	31.79	6.03	119,990
Distillery grains (dried), principally corn	93.0	21.93	38.09	10.83	157,340
Distillery grains (dried), principally rye	93.2	10.38	42.48	6.38	125,243
Atlas gluten feed (distillery by-product)	92.6	23.33	35.64	11.88	159,818
Rye bran	88.2	11.47	52.40	1.79	126,352
Wheat bran, all analyses	88.5	12.01	41.23	2.87	111,138
Wheat middlings	84.0	12.79	53.15	3.40	136,996
Wheat shorts	88.2	12.22	49.98	3.83	131,855
Buckwheat bran	88.5	19.29	31.65	4.56	113,992
Buckwheat middlings	88.2	22.34	36.14	6.21	134,979
Cotton-seed feed	92.0	9.65	38.57	3.37	103,911
Cotton-seed meal	91.8	37.01	16.52	12.58	152,653
Cotton-seed hulls	88.9	1.05	32.21	1.89	69,839
Linseed meal (old process)	90.8	28.76	32.81	7.06	144,313
Linseed meal (new process)	90.1	30.59	38.72	2.90	141,155
Sugar-beet pulp (fresh)	10.1	0.63	7.12	....	14,415
Sugar-beet pulp (dry)	93.6	6.80	65.49	....	134,459
Milk and its by-products:					
Whole milk	12.8	3.38	4.80	3.70	30,829
Skim milk, cream raised by setting	9.6	3.10	4.61	0.90	18,139
Skim milk, cream raised by separator	9.4	3.01	5.10	0.30	16,351
Buttermilk	9.0	2.82	4.70	0.50	16,097
Whey	6.2	0.56	5.00	0.10	10,764

FUEL VALUE.

The last column in the above table, headed "fuel value," indicates the heat and energy power of the food. As stated above, one of the primary functions of the food is to produce heat for the body and energy for work. The value of food for this purpose is measured in "heat units" or "calories,"[1] and is calculated from the nutrients digested. Thus the fuel power of 1 pound of digestible fat is estimated to be 4,220 calories, and of 1 pound of digestible protein or carbohydrates about 1,860 calories. The total fuel value of a feeding stuff is found by using these factors.

The meaning of the figures in the above table is that in 100 pounds of green corn fodder containing an average amount of dry matter (20.7 pounds) there are contained approximately 1.10 pounds of digestible protein (materials containing nitrogen), 12.08 pounds of digestible carbohydrates (starch, sugar, fiber, etc.), and 0.37 pound of digestible fat; and that these materials when consumed in the body will yield 26,076 calories of heat, furnishing energy for work and maintaining the temperature of the body.

FOOD REQUIREMENTS OF ANIMALS.

It will be remembered that the primary functions of food are to repair the waste of the body, to promote growth in immature animals, and to furnish heat and energy. And for these purposes only the digestible portion of the food, as given in the above table, is to be taken into account. The amount of digestible protein, fat, and carbohydrates in a ration is an indication of its fitness to fulfill these purposes. The next question is, How much of these materials does an animal require, and in what proportion should they be given? This differs with the purpose for which the animal is kept, whether it is growing, being fattened, used for work, or making milk. An ox standing in the stall requires less food nutrients than one which is worked hard every day. That is, in drawing heavy loads the animal breaks down or consumes a certain amount of muscular tissue, which must be replaced by protein in the food, and it uses energy or force which is also furnished by the food nutrients. In standing in the barn it still requires some protein, fat, and carbohydrates to perform the necessary functions of the body to maintain heat in winter, to grow a new coat of hair, etc. But if it is fed the same ration as when working hard, the tendency is to get fat or waste the food.

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[1] A calorie of heat is the amount required to raise the temperature of a pound of water about 4° F.

FOOD REQUIRED BY COWS.

The cow requires not only materials for maintenance, but must also have protein, fat, and carbohydrates to make milk from. The milk contains water, fat, protein (casein, or curd), sugar, and ash, and these are all made from the constituents of the food. If insufficient protein, fat, and carbohydrates are contained in the food given her, the cow supplies this deficiency for a time by drawing on her own body, and gradually begins to shrink in quantity or quality of milk, or both. The stingy feeder cheats himself as well as the cow. She may suffer from hunger although her belly is full of swale hay, but she also becomes poor and does not yield the milk and butter she should. Her milk glands are a wonderful machine, but they can not make milk casein (curd) out of the constituents in coarse, unappetizing, indigestible swale hay or sawdust any more than the farmer himself can make butter from skim milk. She must not only have a generous supply of good food, but it must contain sufficient amounts of the nutrients needed for making milk. Until this fact is understood and appreciated, successful, profitable dairying is out of the question.

Many forcible illustrations of its truthfulness have been furnished by the agricultural experiment stations.

RESULTS OF CARE AND FEEDING.

For example, at the Kansas Experiment Station a herd of 20 common scrub cows, which "were below the average cows of the State," were tested to see what could be made of them by proper feeding and handling. The average annual yield of milk per cow under such conditions was 5,707 pounds, the poorest cow giving 3,583 pounds; and the average yield of butter fat was 238 pounds, the poorest cow giving 135.7 pounds. The value of the butter fat averaged $37.75 per cow. To compare this with the conditions in the State, the records were collected of 82 herds in one of the leading dairy sections. The average annual yield was found to be 3,441 pounds of milk per cow, and 104.5 pounds of butter fat, the value of which was $19.79.

We attribute the greater yield secured from the college scrub herd to three causes: First, at all times their rations were either balanced or contained an excess of protein—the material which builds blood and milk—while the Kansas cow usually, when on dry feed, has only half enough protein. Second, kindness and shelter. Our scrub cows were petted, comfortably sheltered, never driven faster than a slow walk, and never spoken to in an unkind tone. Third, a full milk yield was secured through the summer drought by giving extra feed.

Prof. T. L. Haecker, of the Minnesota Experiment Station, made the statement a few years ago that "the average cow in Minnesota is returning in dairy products a sum barely equal to the market price of the feed, simply because of a lack of understanding of how to feed." The average gross return for all the common cows at the Minnesota station, which "are no better than the average cow of Minnesota," was valued at $44.53 per cow. The average gross return to farmers of the State, as shown by the creamery returns, was only about $22 per cow. This deficiency of $22.53 in the returns from the common cows of the State, Professor Haecker believes it is fair to conclude, is "wholly due to lack of knowledge of proper feeding and care."

The cow must be regarded as a sort of living machine. She takes the raw materials given her in the form of food and works them over into milk. If the supply of proper materials is small, the output will be small. The cow that will not repay generous feeding should be disposed of and one bought that will. There are, of course, certain inbred characteristics or natural qualities which even liberal feeding can not overcome.

FEEDING STANDARDS FOR DIFFERENT KINDS OF ANIMALS.

Attempts have been made to ascertain the food requirements of various kinds of farm animals under different conditions. Large numbers of feeding experiments have been made under varying conditions with this end in view. From the results feeding standards have been worked out which show the amounts of digestible protein, fat, and carbohydrates supposed to be best adapted to different animals when kept for different purposes.

These so-called physiological standards refer primarily to the nutrients required for maximum production, but do not take into account the element of cost. Since certain of the nutrients can replace one another, it often transpires that the physiological standard does not correspond with the standard for most economical production in a given locality. This applies more especially to the protein, which is the most expensive nutrient, but as a matter of fact it has often been found in practical experience that production has been increased and cheapened by making the rations conform more nearly to those suggested by the physiological standard.

GERMAN STANDARDS.

The feeding standards prepared by Wolff, a German investigator in animal nutrition, have been the most widely used of any. These were based largely on the weight of the animal, although an attempt was made to make allowance for the age of the animal and for the kind of work performed. Of late, however, there has been a quite general belief that the standards should take more account of the amount or character of production. In the case of milch cows, for example, it is thought that the standard should be adapted to the amount of milk produced, making the live weight a matter of secondary consideration. The most important use of protein in feeding cows is in the formation of milk. Hence a cow producing 20 quarts of milk a day will require considerably more protein to elaborate this milk than one giving only 8 quarts; and as the milk production of cows bears no particular relation to the live weight, a hundred pounds in weight more or less need make very little difference in the ration. The use of rations varying in accordance with the milk production is comparatively simple, as it only requires that the weight of milk given by different cows shall be known. Wolff's standards have recently been modified by Prof. F. Lehmann, as the result of additional experiments and practical experience, and also in the attempt to adapt them more closely to the practical needs of the animal. These standards are as follows:

Wolff-Lehmann feeding standards.

[Showing amounts of nutrients per 1,000 pounds live weight for a day's feeding.]

Animal.	Total dry matter.	Digestible nutrients.			Fuel value.
		Protein.	Carbohydrates.	Fat.	
Oxen:	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Calories.*
At rest in stall	18	0.7	8.0	0.1	16,600
At light work	22	1.4	10.0	0.3	22,500
At medium work	25	2.0	11.5	0.5	27,200
At heavy work	28	2.8	13.0	0.8	32,755
Fattening cattle:					
First period	30	2.5	15.0	0.5	34,650
Second period	30	3.0	14.5	0.7	35,500
Third period	26	2.7	15.0	0.7	35,900
Milch cows:					
Giving 11 pounds milk a day	25	1.6	10.0	0.3	22,850
Giving 16½ pounds milk a day	27	2.0	11.0	0.4	25,850
Giving 22 pounds milk a day	29	2.5	13.0	0.5	30,950
Giving 27½ pounds milk a day	32	3.3	13.0	0.8	33,700
Sheep:					
Coarse wool	20	1.2	10.5	0.2	22,600
Fine wool	23	1.5	12.0	0.3	26,400
Breeding ewes, with lambs	25	2.9	15.0	0.5	35,400
Fattening sheep:					
First period	30	3.0	15.0	0.5	35,600
Second period	28	3.5	14.5	0.6	36,000
Horses:					
Light work	20	1.5	9.5	0.4	22,150
Medium work	24	2.0	11.0	0.6	26,700
Heavy work	26	2.5	13.3	0.8	32,750
Brood sows	22	2.5	15.5	0.4	35,170

Wolff-Lehmann feeding standards—Continued.

[Showing amounts of nutrients per 1,000 pounds live weight for a day's feeding.]

Animal.	Total dry matter.	Digestible nutrients.			Fuel value.
		Protein.	Carbohydrates.	Fat.	
Fattening swine:	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Calories.*
First period	36	4.5	25.0	0.7	57,800
Second period	32	4.0	24.0	0.5	54,200
Third period	25	2.7	18.0	0.4	40,200
Growing cattle:					
Dairy breeds—					
2 to 3 months old, weighing about 150 pounds	23	4.0	13.0	2.0	40,050
3 to 6 months old, weighing about 300 pounds	24	3.0	12.8	1.0	33,600
6 to 12 months old, weighing about 500 pounds	27	2.0	12.5	0.5	29,100
12 to 18 months old, weighing about 700 pounds	26	1.8	12.5	0.4	28,300
18 to 24 months old, weighing about 900 pounds	26	1.5	12.0	0.3	26,350
Beef breeds—					
2 to 3 months old, weighing about 160 pounds	23	4.2	13.0	2.0	40,450
3 to 6 months old, weighing about 330 pounds	24	3.5	12.8	1.5	36,650
6 to 12 months old, weighing about 550 pounds	25	2.5	13.2	0.7	32,150
12 to 18 months old, weighing about 750 pounds	24	2.0	12.5	0.5	29,100
18 to 24 months old, weighing about 950 pounds	24	1.8	12.0	0.4	27,350
Growing sheep:					
Wool breeds—					
4 to 6 months old, weighing about 60 pounds	25	3.4	15.4	0.7	37,900
6 to 8 months old, weighing about 75 pounds	25	2.8	13.8	0.6	33,400
8 to 11 months old, weighing about 80 pounds	23	2.1	11.5	0.5	27,400
11 to 15 months old, weighing about 90 pounds	22	1.8	11.2	0.4	25,850
15 to 20 months old, weighing about 100 pounds	22	1.5	10.8	0.3	24,150
Mutton breeds—					
4 to 6 months old, weighing about 60 pounds	26	4.4	15.5	0.9	40,800
6 to 8 months old, weighing about 80 pounds	26	3.5	15.0	0.7	37,350
8 to 11 months old, weighing about 100 pounds	24	3.0	14.3	0.5	34,300
11 to 15 months old, weighing about 120 pounds	23	2.2	12.6	0.5	29,650
15 to 20 months old, weighing about 150 pounds	22	2.0	12.0	0.4	27,750
Growing swine:					
Breeding stock—					
2 to 3 months old, weighing about 50 pounds	44	7.6	28.0	1.0	70,450
3 to 5 months old, weighing about 100 pounds	35	5.0	23.1	0.8	55,650
5 to 6 months old, weighing about 120 pounds	32	3.7	21.3	0.4	48,190
6 to 8 months old, weighing about 200 pounds	28	2.8	18.7	0.3	41,250
8 to 12 months old, weighing about 250 pounds	25	2.1	15.3	0.2	33,200
Growing fattening swine:					
2 to 3 months old, weighing about 50 pounds	44	7.6	28.0	1.0	70,450
3 to 5 months old, weighing about 100 pounds	35	5.0	23.1	0.8	55,650
5 to 6 months old, weighing about 150 pounds	33	4.3	22.3	0.6	52,000
6 to 8 months old, weighing about 200 pounds	30	3.6	20.5	0.4	46,500
9 to 12 months old, weighing about 275 pounds	26	3.0	18.3	0.3	40,900

For an unworked ox of 1,000 pounds the standard calls for 0.7 pound of digestible protein, 8 pounds of digestible carbohydrates, and 0.1 pound of digestible fat, which would furnish 16,600 calories of heat and energy. When heavily worked the same ox would require, according to the standard, food with four times as much protein and of nearly twice the fuel value. A cow giving 25 pounds of milk would require as much protein and about as much carbohydrates and fat as the heavily worked ox. A ration furnishing the protein, fat, and carbohydrates in the right proportion is said to be a "balanced" ration. If it contains too much carbohydrates and too little protein it is not well balanced.

In addition to furnishing the requisite amounts of nutrients the food must have a certain bulk. The required bulk is secured by feeding a certain amount of coarse fodder, which aids digestion and helps to keep the animal satisfied and healthy. The measure of the bulk or total solid matter is the weight of dry matter in the ration. The dry matter is the solid or water-free portion of the food. More latitude is allowable in this than in the case of any single nutrient.

VALUE OF FEEDING STANDARDS.

It should be borne in mind that feeding standards are simply a concise and approximate statement of the amounts of the different nutrients required by animals, as indicated by the results of experiments and observation. They are not to be regarded as infallible or as absolute formulas which can be followed blindly without regard to the conditions. They are intended to apply to the average conditions. No single standard can be laid down for all conditions. Good judgment and intelligent observation on the part of the feeder are necessary in the application of feeding standards, as the calculation of economical rations is not merely a matter of applied mathematics. The local conditions as regards the feeding stuffs which can be grown and purchased economically, and the value of the products, will have much to do in determining how closely the feeder can afford to adhere to the standard. But such standards or formulas, used in connection with the feeder's observation of his animals and the markets, are very useful, and have served a good purpose in improving the practice of feeding. It is in their abuse that the chief danger lies.

CALCULATION OF RATIONS.

The calculation of rations with the aid of the feeding standards and tables given above will prove both interesting and profitable, for it will throw much light on the proper combinations of food for different purposes. At the same time it promotes a spirit of inquiry and close observation on the part of the farmer, which is one of the first requisites of a successful feeder. The standard for a cow of 1,000 pounds weight, and giving 16½ pounds (about 8 quarts) of milk per day, calls for 2 pounds of protein, 11 pounds of carbohydrates, and 0.4 pound of fat, which would furnish 25,850 calories of heat. A ration can be made up furnishing approximately these amounts of protein, fat, and carbohydrates, but as the carbohydrates and fat serve practically the same purpose in nutrition, an excess of one may make up for a slight deficiency of the other.

RATION FOR A DAIRY COW.

Let us calculate the daily ration for a cow giving about 8 quarts of milk a day, assuming that the farmer has on hand clover hay, corn fodder, corn meal, and wheat bran. From the table showing the amounts of digestible nutrients (p. 8) we find that 100 pounds of clover hay furnishes 7.38 pounds of protein, 38.15 pounds of carbohydrates, and 1.81 pounds of fat, equivalent to a fuel value of 92,324 calories. Ten pounds would have 0.74 pound of protein, 3.81 pounds of carbohydrates, and 0.18 pound of fat, giving a fuel value of 9,232 calories. In the same way the amounts furnished by 10 pounds of dry corn fodder, 3 pounds of corn meal, and 3 pounds of wheat bran are found. The result would be the following amounts:

Method of calculating ration for dairy cow.

Ration.	Digestible protein.	Digestible carbohydrates.	Digestible fat.	Fuel value.
	Pounds.	*Pounds.*	*Pound.*	*Calories.*
10 pounds clover hay	0.74	3.81	0.18	9,232
10 pounds corn fodder	.23	3.23	.11	6,936
3 pounds corn meal	.19	1.96	.10	4,434
3 pounds wheat bran	.36	1.23	.08	3,334
Total	1.52	10.23	.47	23,936
Standard for cow giving 8 quarts of milk a day	2.00	11.00	.40	25,850

This ration is below the standard, especially in protein. To furnish the protein needed without increasing the other nutrients too much, a feeding stuff quite rich in protein is needed. The addition of 2 pounds of Buffalo gluten meal would make the ration contain:

Completed ration for dairy cow.

Ration.	Digestible protein.	Digestible carbohydrates.	Digestible fat.	Fuel value.
	Pounds.	*Pounds.*	*Pound.*	*Calories.*
10 pounds clover hay, 10 pounds corn fodder, 3 pounds corn meal, and 3 pounds wheat bran	1.52	10.23	0.47	23,936
2 pounds Buffalo gluten meal	.43	.86	.23	3,404
Total	1.95	11.09	.70	27,340

This gives nearly the amounts of the several nutrients called for by the standard, although it contains a little more fat, the effect of which is shown in increasing the fuel value above the standard slightly. The ration conforms sufficiently close to the standard, however, and as near as will often be practicable. Although a calculation of the dry matter would show it to be somewhat below the standard, the bulk of material furnished is ample, and there would be no advantage in increasing it by feeding some very coarse material, like straw or swale hay, in place of a part of the corn fodder or hay.

Since the prime objects of food are to repair the waste of the body (or promote growth) and produce heat and energy, the calculation may be considerably simplified by considering only the protein and the fuel value, without impairing accuracy. For example, suppose it is desired to calculate a ration for cows giving about 22 pounds (11 quarts) of milk a day, the supply of feeds being timothy hay, corn silage, corn, bran, and Chicago gluten meal:

Simplified calculation of rations for cows.

Rations.	Protein.	Fuel value.
	Pounds.	*Calories.*
8 pounds rowen hay	0.58	7,683
30 pounds silage	.36	9,913
3 pounds corn meal	.19	4,434
4 pounds bran	.48	4,445
3 pounds Chicago gluten meal	.99	4,677
Total	2.60	31,152
Standard ration	2.50	30,950

This is slightly in excess of the standard, but the proportion is right, so that a little less of the ration might be fed and still meet its requirements. However, as mentioned above, such calculations are not mathematically accurate, owing to variations in the composition and digestibility of feeding stuffs at different times, nor are the so-termed standards exact, but merely approximate statements of the general requirements of animals. It is useless to attempt, therefore, to calculate the rations to hundredths of a per cent. The most that can be safely done is to compound a well-balanced ration, and then by closely watching the cows add to or reduce it, as seems to suit the case of the individual animals, or groups of animals, as indicated by their production and their general condition. It is granted, of course, that no feeding formulas can take the place of the good judgment of the feeder. They are merely aids in that direction.

Adjustment of ration to milk yield.—In making allowance for the difference in milk yield of different cows, a uniform basal ration can be fed to all the cows, and the amount of the richer grain mixture varied to suit the demands. For example, a basal ration might be made up of 25 pounds of corn silage, 8 pounds of rowen hay, and 3 pounds each of corn meal and wheat bran, which would supply 1.43 pounds of protein and a fuel value of 23,712 calories. To this could be added a richer grain mixture composed of two parts of gluten meal and one part of cotton-seed meal, the amount of this being varied according to the milk yield of the cow. Two pounds of this mixture would bring the ration up to 1.97 pounds of protein and 26,999 calories, which would meet the requirements of cows giving 12 to 15 pounds of milk a day, while 4 pounds would bring it up to 2.50 pounds of protein and 30,286 calories of heat, suitable for the cows giving 20 to 25 pounds of milk, and so on, 5 or 6 pounds of the grain mixture being fed to the heavier milkers.

RATION FOR STEERS.

A ration composed of 10 pounds of shelled corn, 5 pounds of wheat bran, 2 pounds of linseed meal (new process), and 10 pounds of corn fodder per steer would furnish the following amounts of protein and energy:

Calculated ration for steers.

Ration.	Protein.	Fuel value.
	Pounds.	*Calories.*
10 pounds shelled corn	0.71	15,722
5 pounds bran	.60	5,557
2 pounds linseed meal	.61	2,823
10 pounds corn fodder	.23	6,936
Total	2.15	31,038

This would correspond approximately to the requirements of yearling steers. The exclusive feeding of shelled corn, as is often practiced in the middle West, gives a poorly balanced ration, as it is not possible to compound a ration of corn and corn fodder or common hay which will not contain a disproportionate amount of fat and carbohydrate constituents. Admixtures of other grains or by-products give better balanced rations, and such rations have usually been found more profitable. Local conditions, however, and the practice of following steers with hogs may alter this.

COTTON-SEED MEAL AND HULLS.

A common practice in fattening steers in the South is to feed 15 to 24 pounds of cotton-seed hulls and 6 to 8 pounds of cotton-seed meal. The nutrients contained in such mixtures are compared with the standard in the following table:

Rations fed to steers in the South.

Ration.	Dry matter.	Digestible protein.	Digestible carbohydrates.	Digestible fat.	Fuel value.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Calories.*
20 pounds hulls and 6 pounds cotton-seed meal	23.29	2.43	7.43	1.13	23,108
20 pounds hulls and 8 pounds cotton-seed meal	25.12	3.17	7.76	1.38	26,153
24 pounds hulls and 6 pounds cotton-seed meal	26.84	2.47	8.72	1.21	25,920
24 pounds hulls and 8 pounds cotton-seed meal	28.68	3.21	9.05	1.46	28,965
Wolff-Lehmann standard:					
First period	30	2.5	15.0	.5	34,650
Second period	30	3.0	14.5	.7	35,500
Third period	26	2.7	15.0	.7	35,900

The trouble with these rations is that they are not well balanced, i. e., they contain too much protein in proportion to the carbohydrates and fat. The hulls give bulk to the ration but do not furnish as much carbohydrates and fat as is required of a coarse fodder when fed with so rich a feed as cotton-seed meal. The rations could be improved by substituting 2 pounds of corn meal in place of an equal amount of cotton-seed meal, or by substituting silage for a part of the hulls. The composition would then be:

Rations for steers in the South.

Ration.	Dry matter.	Digestible protein.	Fuel value.
	Pounds.	*Pounds.*	*Calories.*
20 pounds hulls, 6 pounds cotton-seed meal, and 2 pounds corn meal	24.99	2.56	26,064
24 pounds hulls, 6 pounds cotton-seed meal, and 2 pounds corn meal	28.54	2.60	28,876
15 pounds hulls, 15 pounds silage, 6 pounds cotton-seed meal, and 2 pounds corn meal	24.38	2.68	27,548
15 pounds hulls, 20 pounds silage, 6 pounds cotton-seed meal, and 2 pounds corn meal	25.66	2.75	29,200

The addition of 2 pounds more of corn meal to these rations would make them better balanced. Whether or not the use of corn meal will prove profitable will depend largely upon the relative prices of cotton-seed meal, hulls, and corn.

RATION FOR PIGS.

As a result of experiments which have been in progress for several years at the Massachusetts State Station, the station recommends the following proportions of skim milk and corn meal, according to the weight of the pig:

Pigs weighing 20 to 70 pounds, 2 ounces of corn meal per quart of skim milk.
Pigs weighing 70 to 130 pounds, 4 ounces of corn meal per quart of skim milk.
Pigs weighing 130 to 200 pounds, 6 ounces of corn meal per quart of skim milk.

The pigs are fed all they will eat up clean. A ration of 5 quarts of skim milk and 20 ounces of corn meal for a pig in the first period, up to 70 pounds weight, would furnish approximately:

Nutrients in ration for young pigs.

Ration.	Dry matter.	Digestible protein.	Digestible carbohydrates.	Digestible fat.	Fuel value.
	Pounds.	*Pound.*	*Pounds.*	*Pounds.*	*Calories.*
10 pounds of skim milk	0.94	0.30	0.51	0.03	1,635
1¼ pounds of corn meal	1.06	.08	.82	.04	1,847
Total	2.00	.38	1.33	.07	3,482
Standard for pig weighing 50 pounds	2.20	.38	1.40	.05	3,522

Buttermilk might be used in place of skim milk, but pound for pound it has not usually given quite as good results as skim milk.

WEIGHT OF ONE QUART OF FEEDING STUFFS.

In calculating rations it is necessary to use weights rather than measures, as the analyses and tables are made on the basis of weight. As the farmer measures the grain given it will be necessary to ascertain the relation between the amount to be given and its measure. For this purpose the following table, showing the weight per quart of a number of feeding stuffs, may be helpful:

Weight of feeding stuffs per quart.

Feeding stuff.	Pound.	Ounces.
Corn, cracked	1	12
Corn meal	1	8
Corn-and-cob meal	1	6
Oats, whole	1	
Oats, ground		12
Wheat, whole	1	14
Wheat bran		10
Wheat bran, coarse		8
Wheat middlings	1	2
Wheat middlings, coarse		13
Rye bran		10
Gluten meal	1	11
Gluten feed	1	3
Linseed meal	1	2
Cotton-seed meal	1	8

Some of these materials, especially by-products like wheat bran, vary considerably in weight, and the above figures can not be regarded as strictly accurate for all cases. Weighing is, of course, always the safer way where it is desired to feed quite definite amounts.

SELECTION OF FEEDING STUFFS.

In selecting feeding stuffs for his stock the farmer will naturally be governed by the conditions of the market. The cost of feeding stuffs is controlled by other factors than the actual amounts of food materials which they contain; indeed, there often appears to be very little connection between the two. Bearing in mind that the protein is the most expensive ingredient, and the one especially sought in concentrated feeds, the farmer can make his selection with the aid of the tables showing the digestible materials in 100 pounds. These will show him whether wheat at 50 cents per bushel is a cheaper feed than corn at 60 cents, and how gluten meal at $23 per ton compares with linseed meal at $27. In these comparisons only the protein and fuel value need necessarily be considered. Of course the special adaptability of some materials to different kinds of animals and different purposes will be taken into account.

MANURIAL VALUE.

But another important consideration where fertilizers or manures have to be relied upon is the manurial value of a feeding stuff. This is shown by the nitrogen in the protein and the phosphoric acid and potash in the ash. Feeding stuffs differ widely in this respect, wheat bran and cotton-seed meal having a high manurial value, while that of corn meal is relatively low. The value of the manure is largely determined by the character of the food given. If the manure is carefully preserved a large proportion of the fertilizing constituents of the feed is recovered in the manure, and goes to enrich the land. This matter has been treated in a separate bulletin on barnyard manure.[1]

It will be seen by referring to the table of feeding stuffs given above that hay from the leguminous crops—clover, lupines, alfalfa, cowpea, etc.—contains about twice the quantity of digestible protein that hay from the grasses does. As a result the former contains much more nitrogen for fertilizing purposes, and is also somewhat richer in potash than grasses. The seeds of these plants (cowpea, soy bean, etc.) are exceedingly rich in protein and can take the place of expensive commercial feeds. By growing and feeding more leguminous crops the amount of grain required is diminished, the value of the manure is increased, and the soil is enriched in fertility. Further than this, it has been demonstrated within the last few years that leguminous crops are able to derive the larger part of this nitrogen from the atmosphere during their growth, requiring little manuring with nitrogenous manures. They therefore enrich the soil, the ration, and the manure in nitrogen which they derive from the atmosphere without cost to the farmer, besides improving the mechanical and physical condition of the soil.[2]

ORIGIN OF BY-PRODUCTS USED AS FEEDING STUFFS.

The by-products resulting from the manufacture of flour, glucose, starch, fermented liquors, etc., are extensively used for feeding purposes, and include many of the richest and most prized feeding stuffs. The manner in which these materials are produced will be briefly described.

By-products from flouring mills.—In the modern processes of making flour from wheat the grain is subjected to successive crushings or grindings. After each of these, the products are separated by screening and blowing into flour, middlings, and bran. The bran consists of the coarser parts of the husk, which are unfit for further grinding, with portions of the gluten layer. The middlings contain small particles of bran as admixtures. These are separated, and go under the name of shorts. The shorts contain less fiber and ash than the bran, although they are of similar origin—the outer coats of the grain. After cleaning, the middlings are graded and reground to flour.

By-products of similar nature result in the milling of rye, buckwheat, rice, etc.

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[1] Farmers' Bulletin No. 21.

[2] See also Farmers' Bulletin No. 16, Leguminous Crops for Green Manuring and for Feeding, by the author of this bulletin.

Hominy chop, meal, and feed result from the manufacture of hominy, and contain the germ and coarser portions of the corn.

By-products from glucose and starch factories.—These include so-called gluten meal, glucose meal, cream gluten, gluten flour, gluten feed, glucose feed, dried sugar feed or meal, maize feed, dried starch feed, and some other materials of similar nature. These are all obtained as by-products in the manufacture of starch and glucose from the starch of corn. The process followed and the treatment of the by-products differs considerably in different factories, which accounts for the wide variations in their composition.

The corn is soaked until it is swollen and soft, and is passed through the mill while wet, the hulls and germs of the corn being rubbed off. In some cases the starch is separated from this mass by means of running water, and the wet residue is dried and sold as gluten feed. In other cases the mass after grinding is bolted, the starch and gluten passing through while the husk and germ remain behind. In some factories the latter (husk and germ) are dried and sold as corn-germ feed, corn-germ meal, etc. In others the material is treated to extract the oil from the germ and then sold under the name of maize feed. The material which passes the bolting cloth is treated to separate most of the starch, and the residue is sold as gluten meal, cream gluten, etc. The Chicago gluten meal, it is said, has had a part of the fat extracted from it. In some cases the gluten meal is mixed with the hulls and germs without the oil being extracted. This is said to be the case with Buffalo gluten feed.

The residues from these factories are frequently sold in their wet condition, containing from 60 to 70 per cent of water, under the names wet starch feed, sugar feed, glucose feed, etc. These wet products must be used at once, as they ferment. The dried products from the same factory often vary considerably in composition from time to time. Owing to these variations and the fact that there is such a variety of names for these products that it is difficult to make any helpful classification, the farmer can only be certain of what he is buying when he buys on a guaranty of composition or from lots that have been analyzed.

By-products from oil mills.—Of these the most common in this country are the cotton-seed meal and linseed meal. The oil is expressed from the hot cotton seed, and the hard cakes remaining are called oil cakes. In Europe this cake is often sold as such for feeding. In this country it is usually ground to a meal.

The composition of cotton-seed meal depends upon the composition of the seed and the completeness of the separation of the hulls and the expression of the oil. The composition of the hulls depends considerably upon the thoroughness with which the kernel and lint are removed. Usually more or less of the kernel adheres to the hulls, increasing the percentage of protein and fat. Linseed meal, or oil meal, as it is often called, is the residue from the separation of oil from flax seed, and is distinguished as old process and new process. In the old process the oil is expressed. In the new process it is more thoroughly removed with the aid of solvents, hence the meal contains less fat.

By-products from breweries and distilleries.—In making malted liquors from grain (usually barley) the grain is malted or allowed to sprout, resulting in the development of diastase, which converts the starch of the grain into sugar. When the process has proceeded far enough it is checked by kiln-drying, the sprouts being removed by machinery and sold for feed under the name of malt sprouts. The grain (then known as malt) is treated with water and the clear wort subsequently drawn off and fermented. The residue of the grain, known as brewers' grains, consists of the hull, germ, gluten, and some of the starch of the grain. It is sometimes sold in the wet condition for immediate use, but when it is to be shipped away is dried, and can then be kept indefinitely.

In making distilled liquors from corn, rye, or other grain, the ground grain is treated with a solution of malt to change the starch into sugar, which is then fermented with yeast and distilled. The residue, or distillery slop, is sometimes fed as such, but, like wet brewers' grains, spoils quickly. It is filtered and dried, and yields a rich distillery feed or distillers' grains. Distinction is made between the grains from corn and from rye, those from corn being the richer in protein and fat. Atlas gluten meal and feed, Golden Gluten, and Grano Gluten are all distillery products and do not properly belong with the gluten meals and feeds, as their names would imply.

SUGAR-BEET PULP AND MOLASSES.

The establishment of beet-sugar factories in this country has led to the production of immense quantities of sugar-beet pulp as a waste material. This is sometimes called "diffusion residue," or "beet chips." It consists of the residue of the beet after the extraction of the sugar under pressure in the diffusion batteries. With the sugar more or less of the other soluble constituents are taken out, and hence the residue is to be regarded as somewhat inferior to the beet before extraction, containing more of the fiber and gums and less soluble constituents. The pulp contains about 90 per cent of water as it comes from the factory. On this account it can not profitably be shipped or hauled any great distance. In some European factories it is dried, but this process is expensive and has not been adopted to any extent in this country. The fresh pulp can frequently be drawn home from the factory at the time the beets are being hauled. Many of the factories have been willing to give it away in order to get rid of it, while others which have a greater demand for it sell it for 50 cents a ton. Still other factories have put up feeding sheds near by, where hundreds of steers and sheep are fed largely upon the pulp with the addition of a little hay.

Results of feeding beet pulp.—One large factory in Nebraska, which has a farm of 12,000 acres connected with it, has erected barns and sheds to accommodate about 16,000 head of sheep. During the season of 1900 this factory fed 32,000 head of sheep. This factory, running at its full capacity, it is expected would furnish feed for about 10,000 head of steers and 50,000 sheep. The manager is a firm believer in the value of beet pulp as a succulent food. He states that he "never saw sheep do better," and when ready for the market they were well fattened, thick-fleshed, plump, and in prime condition. The meat was juicy and of excellent quality.

Prof. Thomas Shaw expresses his belief that sugar-beet pulp can be fed more advantageously to cattle and sheep that are being fattened than to dairy cows. The New York Cornell Experiment Station, however, found that this material gave good results with milch cows, the dry matter (solids) in it being about equal in value to that in corn silage. German experiments with beet pulp for cows have also given good results, the flow of milk being maintained in a satisfactory manner. Some Danish experiments have shown that, as compared with mangels, the butter produced on sugar-beet pulp was of about equal quality and kept fully as well. Where large quantities of the pulp were fed the cream required to be churned a few minutes longer.

In practice, about 10 pounds of pulp per day is fed to sheep, and 50 to 75 pounds to cattle. The amount in the latter case, however, is said to depend on the cattle, and more may be given, up to 100 pounds, if they will eat it. The pulp is believed to effect a considerable saving in the amount of grain required for fattening.

Preservation in silos.—Sugar-beet pulp can be successfully preserved in silos and makes a very fair quality of silage. It is relished by cattle, even the slightly spoiled portions not being distasteful to them. In Europe the silos consist of trenches or pits dug in the ground, but the ordinary silo used in making corn silage will undoubtedly preserve the material with less loss.

Benefits of feeding pulp.—As the sugar-beet crop is an exhaustive one, and the fertility of the soil can be maintained by feeding the pulp, it becomes quite an important matter that farmers growing sugar beets should combine with it the feeding of the pulp where practicable. Prof. W. A. Henry states as his belief that "a farming community which will intelligently grow beets and utilize the pulp resulting from them in the feeding of cattle, will be able to grow as large crops in addition to the beets as were produced before adding that industry, and to maintain more cattle than was possible before beet farming was inaugurated. This statement is warranted by the conditions prevailing in the beet districts of Europe. Beet culture means more cattle and larger crops generally, rather than less, provided always that the pulp from the beets is properly utilized."

SUGAR-BEET MOLASSES.

This is another product of the beet-sugar manufacture, which accumulates in large quantities. On account of the salts which it contains, this molasses can not be disposed of for human consumption. It has a bitter taste and is purging in its effects. In Europe it has been found to possess considerable value for feeding. For this purpose it has been mixed with peat, dried blood, beet pulp, or with a mixture of feeding stuffs, such as bran and palm-nut meal, in order that it might be more conveniently handled. The molasses contains from 40 to 50 per cent of sugar, which is all digestible, and it is upon this constituent that its feeding value almost entirely depends. In European experiments no deleterious results have been noticed even when 4 or 5 pounds of molasses per day was fed. It has given good results with milch cows and is regarded as an excellent food for horses, being readily eaten. Experiments in feeding it to steers at the Canada Experimental Farms were favorable to its use, as the animals became very fond of it and it stimulated their appetite.

PREPARATION OF FOOD FOR ANIMALS.

One point upon which there seems to be much misunderstanding is as to the influence of previous treatment of the food on its digestibility. Thus, for example, the effect of drying hay is not to lessen its digestibility, as is often believed. The soluble materials may be washed out if the hay is rained upon, and the tender parts may be lost in harvesting, but in ordinary haymaking the water of the grass is largely dried out without the digestibility of the constituents being materially affected. Hay stored for a long time, even when kept dry and not allowed to heat, appears to lose a part of its value as food.

COOKING AND STEAMING FOOD.

There has been considerable misconception as to the value of cooking or steaming food for stock. Experiments abroad have indicated that cooking or steaming coarse or unpalatable food was advantageous, not on account of making the food more nutritious, but in inducing the animals to eat larger quantities of it. In fact it has been shown for lupine hay and some other materials that the digestibility of certain of the food ingredients, notably the albuminoids, was diminished by steaming; and the cooking of potatoes, which was formerly believed advantageous, has been shown to be of no advantage whatever in case of milch cows, although it was of some advantage to pigs. Julius Kühn, in his book on feeding, says:

> Unless large amounts of straw and coarse foods are to be fed and the supply of good hay and hoed crops is scarce, it will usually be more profitable to omit the steaming. If the reverse condition prevails, steaming will be found a very advantageous means of inducing the animals to eat sufficiently large quantities of the food.

Ladd, while connected with the New York State Station, reported analyses of cooked and uncooked clover hay and corn meal, and determinations of the digestibility of the same. These showed that the percentage of albuminoids and fat and the relative digestibility of the albuminoids were more or less diminished by cooking.

Cooking grain.—The experiments made by our experiment stations in preparing food have been mostly with pigs. At least thirteen separate series of experiments in different parts of this country have been reported on the value of cooking or steaming food for pigs. In these, cooked or steamed barley meal, corn meal, and shorts; whole corn; whole corn and shorts; peas, corn and oatmeal; potatoes, and a mixture of peas, barley, and rye have been compared with the same foods uncooked (and usually dry). In ten of these trials there has not only been no gain from cooking, but there has been a positive loss, i. e., the amount of food required to produce a pound of gain was larger when the food was cooked than when it was fed raw, and in some cases the difference has been considerable. In the three exceptional cases there was either no gain at all or only very slight gain from cooking or steaming, amounting to 2 per cent in one case.

Steaming cotton seed.—Experiments in feeding steamed cotton seed to cows are reported by the Mississippi Station. The station concludes from three years' work that "the milk and butter from cows fed on steamed cotton seed cost less than that from cows fed on raw cotton seed and but little more than one-half as much as that from cows fed on cotton-seed meal. The butter from steamed cotton seed is superior in quality to that from either raw seed or cotton-seed meal." The Texas Station finds it advantageous to boil cotton seed for steers.

MOISTENING AND SOAKING FOOD.

Three stations have reported comparisons of dry with wet or soaked food for pigs. The food consisted of shelled corn in one case, of a mixture of corn meal and shorts in another, and of a mixture of corn meal, shorts, and linseed meal in a third. In every case the pigs ate more of the wet food and made larger gains on it. The additional gain was usually due to the larger amount of food eaten when moistened or soaked. The Kansas Station has just reported an experiment in soaking corn for steers. The shelled corn for one lot (5 steers) was soaked until it began to soften, and that for the other lot (5 steers) was fed dry. From November 7 to April 6 the lot on soaked corn ate 282 bushels of corn and gained 1,632 pounds, while the other lot ate 290 bushels of corn and gained only 1,468 pounds—a difference of 164 pounds. Owing to their better condition the steers fed soaked corn brought a higher price, giving a balance of $25.50 in favor of soaking. The conclusion is that it will pay to soak corn for steers if it can be done for 6 cents a bushel. Soaking wheat for pigs is quite generally recommended.

CUTTING COARSE FODDER.

The Maine Station compared the value of chopped and unchopped hay for cows, and found no evidence that the chopping had any effect. The Indiana Station found that steers made better gains on cut than on uncut clover hay. Cutting corn stover was found advantageous at the Wisconsin Station. In reference to cutting coarse fodder Professor Henry says:

> There should be a good feed cutter on every dairy farm, useful for silo filling in the fall and for chaffing feed in the winter. All cornstalks should be put through this machine, for then they are in better condition for feeding, and the coarser portions left uneaten are in good form for bedding and the manure heap. Long cornstalks are a nuisance in the feeding manger, worthless for bedding, and troublesome in the manure pile. Many farmers find difficulty in feeding cut cornstalks, since sometimes the cows refuse to eat them. In a few cases we have found that the sharp ends of the cornstalks, when cut certain lengths, injure the mouths of the cows. Where they are not well eaten the cause is often due to overfeeding, or endeavoring to have the cows live on too limited a variety of foods. Keep the mangers clean and feed the cut fodder with care, and usually very little will be left over, and that only the coarsest portion. Experiments at the Wisconsin Station show that with the varieties of corn raised there much more of the cut stalks will be eaten than if fed uncut under the same conditions.

THE VALUE OF SUCCULENT FEEDS.

The use in this country of some kind of succulent feed nearly the whole year round, to keep up the appetite and the general condition of the animals, has become quite general. In Europe roots are largely grown for this purpose. In this country roots are not grown to any great extent in comparison with corn, which furnishes a larger and cheaper supply of food material from a given area than any other crop. The work of the experiment stations has shown that fodder corn yields about twice as much dry matter as a crop of roots grown on the same land. While the dry matter in beet roots is somewhat more digestible than that in corn silage, it has been found in feeding experiments that dairy cows fed rations consisting quite largely of either beets or silage have given rather better returns for the dry matter in the silage. The loss of nutrients in preserving corn in the form of silage and as dry corn fodder is about the same when careful methods are employed, but feeding trials with dairy cows have shown that silage gives rather better results than a corresponding amount of dry corn fodder. Furthermore, there is less waste in feeding it, as the animals eat the butts readily in the form of silage, but reject them in the form of corn fodder, even when cut fine. Silage proves more acceptable to stock than dry fodder, and they will consume a larger amount of dry matter in that form.

The use of succulent food in the form of corn silage has, therefore, become very prevalent in localities where corn is a leading forage crop. It is found adapted to nearly all kinds of farm animals, including horses, sheep, and pigs.

SOILING.

This term is used to mean the feeding of farm animals, more or less confined, on green forage fresh from the fields. The practice is more prevalent in older countries where land is expensive, and is coming into use in some localities in the eastern part of this country to such an extent as to entitle it to recognition as one of the systems of feeding. Partial soiling is much more common, being relied upon to carry the animals over a period when pastures are short. Under the soiling system a larger number of animals can be kept upon a given acreage, and by allowing open-air exercise in a large yard or pasture the practice has been demonstrated as entirely feasible for dairy animals.

SOILING DAIRY COWS.

The Wisconsin Station found that 1 acre of soiling crops was equal to about 2½ acres of good blue-grass pasture for feeding dairy cows, and the Connecticut Storrs Station kept 4 cows from June 1 to November 1 on soiling crops produced on 2½ acres of land.

The New Jersey Experiment Station has been conducting a practical trial in soiling dairy cows for a number of years past, and finds that complete soiling is entirely practicable, i. e., that green forage crops may serve as the sole food of the dairy herd, aside from the grain ration, without injury to the animals and with a considerable saving in the cost of milk. A forage-rotation system has been worked out so as to furnish a continuous supply of green crops throughout the season. One acre of soiling crops produced sufficient fodder for an equivalent of 3½ cows for six months. Rye, corn, crimson clover, alfalfa, oats and peas, and the millets have been found to furnish food more economically than any other green crops in that locality. A grain ration was always fed in addition to the soiling crops.

The station holds that "where complete soiling is not practicable it will pay to grow forage crops to supplement pasturage during drought or shortage due to other causes, and thus furnish a sufficient and continuous supply of food from the farm." The added labor involved in growing and harvesting these green crops should be taken account of. As an average cow or steer will consume from 60 to 100 pounds of green forage a day, the labor involved in supplying green food for a large herd is quite an item. Partial soiling properly conducted will be found a profitable practice on many farms, enabling more stock to be kept and maintaining a continuous flow of milk, and good growth in the case of steers, throughout the season when pastures are likely to be short.

CONDIMENTAL FEEDING STUFFS.

A considerable number of proprietary articles sold under trade names are found on the markets in this country. Judging from the extent to which they are advertised and statistics which have been collected from feeders, the employment of these prepared or condimental feeds must be quite extensive. Extravagant claims are made for them as to their effect upon the general health of animals and their feeding value or their ability to increase milk production. Tonic or medicinal properties are claimed for many of them. They frequently contain a large quantity of salt, some fenugreek, aromatic seeds, charcoal, Epsom salts, sulphur, cayenne, gentian, ginger, etc.

Analyses of samples of these feeding stuffs collected from time to time show that none of them can be regarded as concentrated feeds in the common acceptation of the term. The basis of the better ones is linseed or flaxseed meal or some cereal by-product. They are usually sold at exorbitant prices, ranging from 10 to 20 cents a pound. Neither the claims made for their valuable properties nor the need of supplying tonics or medicines with the food will justify the feeder in buying such materials. The Connecticut State Experiment Station has recently exposed a number of these condimental feeds for which claims wholly without ground were made.

The mildly curative properties of the various drugs used in these feeds are well understood by most dairy farmers, as well as their limitations. The claims that by the use of condiments and spices the digestibility of food can be increased, and in this way a saving of feeding can be effected, have no basis in fact. No experiments have demonstrated or made even probable such an effect.

INSPECTION OF FEEDING STUFFS.

A number of the Eastern States have passed laws requiring that the composition of certain classes of feeding stuffs be guaranteed by the manufacturers, and providing an inspection of these goods to see that the guaranty is complied with. These laws apply only to the so-called concentrated feeding stuffs, especially the by-products and mixed feeds, not the cereal grains sold as such. The inspection is usually in charge of the experiment station and is managed very similarly to the fertilizer inspection. The results are published in bulletins, which enable the farmer to judge as to the reliability of these goods and assist him in making an economical selection.

NECESSITY FOR INSPECTION.

The need for this inspection arises from the quite wide variation in the composition of many of the by-products, the confusion of names, as in the case of the by-products from starch manufacture, the large number of mixed feeds which are put upon the market under proprietary names, and the occasional tendency to mix with the material substances of inferior value. The variation which occurs in the composition of some of the most common concentrated feeding stuffs is readily shown by the compilation of analyses given at the end of this bulletin. Wheat bran, for example, varies in protein all the way from 12 to 19 per cent, wheat middlings from 10 to 20 per cent, buckwheat middlings from 25 to 31 per cent, cotton-seed meal from 23 to 50 per cent, etc., while the various materials sold under the name of gluten meal have been found to vary from less than 20 to over 40 per cent. These variations are, for the most part, due to slight differences in the method of treatment and in the original material used rather than to adulteration, but they are none the less misleading to the farmer.

In the trade names which have been given to the different by-products great confusion has arisen, so that only one familiar with the processes of manufacture could tell the class to which the different materials belong. In some cases the names appear to have been purposely made delusive.

Of recent years there have been a large number of mixed stock feeds placed upon the market for which extraordinary claims have often been made. Some of these serve as an outlet for the light oats and hulls from oatmeal factories, and other by-products. One so-called concentrated dairy feed recently reported upon contained, on the average, less than 8 per cent of protein and 3.4 per cent of fat, while it had over 22 per cent of fiber, which warrants the conclusion that it is "concentrated" in fiber chiefly.

No very considerable amount of actual adulteration has been observed in this country, although ground cotton-seed hulls have been mixed with cotton-seed meal and peanut shells, oat hulls, and similar products with other materials in a manner that must be considered adulteration.

SOME RESULTS OF INSPECTION.

The feeding stuff inspection protects the farmer from fraud in the same way that the fertilizer inspection does, and gives him the benefit of a guaranteed composition in buying. The result of this inspection, which has been in operation for a number of years, has been quite marked in driving inferior grades of goods, like adulterated cotton-seed meal, out of the market, and tending to bring about greater uniformity in composition in the case of standard by-products.

APPENDIX.

COMPOSITION OF FEEDING STUFFS.

In the following table the composition of a large number of feeding stuffs in common use is given from American sources, previous tables being revised for this purpose. Not only are the averages given, but also the highest and lowest result found for each ingredient in the various materials. That is, in the case of the minimum and maximum the figures given do not represent the results of single analyses, but are the highest and lowest results which have been found in the case of each ingredient. They are given to show the limits within which each ingredient has been found to vary.

Composition of feeding stuffs.

Feeding stuff.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Number of analyses.
GREEN FODDER.							
Corn fodder:[1]							
Flint varieties—	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Minimum	51.5	0.7	0.6	2.1	4.3	0.3	
Maximum	90.8	1.8	4.0	11.4	36.3	1.3	
Average	**79.8**	**1.1**	**2.0**	**4.3**	**12.1**	**0.7**	40
Flint varieties cut after kernels had glazed—							
Minimum	69.7	0.9	1.5	3.0	10.0	0.6	
Maximum	83.7	1.7	2.7	6.1	19.7	1.3	
Average	**77.1**	**1.1**	**2.1**	**4.3**	**14.6**	**0.8**	10
Dent varieties—							
Minimum	59.5	0.6	0.5	2.0	3.0	0.1	
Maximum	93.6	2.5	3.8	11.0	27.0	1.6	
Average	**79.0**	**1.2**	**1.7**	**5.6**	**12.0**	**0.5**	63
Dent varieties cut after kernels had glazed—							
Minimum	59.5	1.0	1.0	5.4	11.6	0.4	
Maximum	80.7	2.2	3.3	8.5	27.0	1.6	
Average	**73.4**	**1.5**	**2.0**	**6.7**	**15.5**	**0.9**	7
Sweet varieties—							
Minimum	69.3	0.8	0.9	1.9	3.2	0.1	
Maximum	92.9	2.6	2.7	8.5	19.4	1.0	
Average	**79.1**	**1.3**	**1.9**	**4.4**	**12.8**	**0.5**	21
All varieties—							
Minimum	51.5	0.6	0.5	1.9	3.0	0.1	
Maximum	93.6	2.6	4.0	11.4	36.3	1.6	
Average	**79.3**	**1.2**	**1.8**	**5.0**	**12.2**	**0.5**	126
Leaves and husks, cut green—							
Minimum	57.9	2.1	1.8	6.6	16.7	1.0	
Maximum	71.3	4.4	2.4	12.5	22.2	1.3	
Average	**66.2**	**2.9**	**2.1**	**8.7**	**19.0**	**1.1**	4
Stripped stalks, cut green—							
Minimum	74.5	0.6	0.4	6.7	14.2	0.4	
Maximum	77.4	0.8	0.6	8.8	16.0	0.6	
Average	**76.1**	**0.7**	**0.5**	**7.3**	**14.9**	**0.5**	4
Kafir corn:							
Minimum	60.5	1.0	1.2	3.7	6.1	0.3	
Maximum	87.6	2.7	3.8	9.5	25.8	1.5	
Average	**73.0**	**2.0**	**2.3**	**6.9**	**15.1**	**0.7**	27
Rye fodder:							
Minimum	74.4	1.3	2.3	4.7	4.9	0.2	
Maximum	84.3	2.4	3.0	14.9	12.4	0.7	
Average	**76.6**	**1.8**	**2.6**	**11.6**	**6.8**	**0.6**	7

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[1] Corn fodder is the entire plant, usually a thickly planted crop. Corn stover is what is left after the ears are harvested.

Composition of feeding stuffs—Continued.

Feeding stuff.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Number of analyses.
GREEN FODDER—continued.							
Oat fodder:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Minimum	31.3	1.5	1.5	7.1	10.8	0.4	
Maximum	78.6	4.2	6.1	16.8	39.8	3.0	
Average	**62.2**	**2.5**	**3.4**	**11.2**	**19.3**	**1.4**	**6**
Redtop,[1] in bloom:							
Minimum	51.5	1.7	2.0	8.0	11.7	0.6	
Maximum	76.2	2.9	4.3	15.7	21.9	1.1	
Average	**65.3**	**2.3**	**2.8**	**11.0**	**17.7**	**0.9**	**5**
Tall oat grass,[2] in bloom:							
Minimum	62.3	1.6	1.7	9.2	13.0	0.6	
Maximum	73.5	3.0	3.3	9.7	20.7	1.5	
Average	**69.5**	**2.0**	**2.4**	**9.4**	**15.8**	**0.9**	**3**
Orchard grass, in bloom:							
Minimum	66.9	1.6	1.9	5.8	9.9	0.7	
Maximum	77.3	2.9	4.1	11.1	16.6	1.3	
Average	**73.0**	**2.0**	**2.6**	**8.2**	**13.3**	**0.9**	**4**
Meadow fescue, in bloom:							
Minimum	67.6	1.6	1.8	10.2	12.5	0.7	
Maximum	73.2	2.0	2.7	11.3	15.7	1.1	
Average	**69.9**	**1.8**	**2.4**	**10.8**	**14.3**	**0.8**	**4**
Italian rye grass, coming into bloom:							
Minimum	69.6	2.1	2.6	5.5	11.5	1.1	
Maximum	76.6	2.8	3.8	7.5	15.4	1.6	
Average	**73.2**	**2.5**	**3.1**	**6.8**	**13.3**	**1.3**	**24**
Timothy,[3] at different stages:							
Minimum	47.0	1.4	1.3	5.1	10.1	0.6	
Maximum	78.7	3.2	3.8	19.4	28.6	2.0	
Average	**61.6**	**2.1**	**3.1**	**11.8**	**20.2**	**1.2**	**56**
Kentucky blue grass,[4] at different stages:							
Minimum	51.7	1.6	2.4	3.8	6.5	0.8	
Maximum	82.5	4.8	7.2	14.8	26.6	1.9	
Average	**65.1**	**2.8**	**4.1**	**9.1**	**17.6**	**1.3**	**18**
Hungarian grass:							
Minimum	62.7	1.9	2.8	7.6	9.1	0.5	
Maximum	78.3	2.2	3.2	10.8	20.1	1.1	
Average	**71.1**	**1.7**	**3.1**	**9.2**	**14.2**	**0.7**	**14**
Red clover, at different stages:							
Minimum	47.1	0.9	1.7	1.8	3.5	0.3	
Maximum	91.8	4.0	7.1	14.7	25.8	1.8	
Average	**70.8**	**2.1**	**4.4**	**8.1**	**13.5**	**1.1**	**43**
Alsike clover,[5] in bloom:							
Minimum	72.3	1.9	3.6	5.3	10.8	0.6	
Maximum	77.3	2.1	4.2	9.4	11.5	1.2	
Average	**74.8**	**2.0**	**3.9**	**7.4**	**11.0**	**0.9**	**4**
Crimson clover:							
Minimum	78.4	1.4	2.7	3.5	7.0	0.6	
Maximum	84.6	2.0	3.5	6.3	9.7	0.8	
Average	**80.9**	**1.7**	**3.1**	**5.2**	**8.4**	**0.7**	**3**
Alfalfa,[6] at different stages:							
Minimum	49.3	1.8	3.5	2.5	10.8	0.6	
Maximum	82.0	5.1	7.7	14.8	11.5	1.2	
Average	**71.8**	**2.7**	**4.8**	**7.4**	**12.3**	**1.0**	**23**
Serradella, at different stages:							
Minimum	65.6	1.8	2.1	2.0	3.9	0.4	
Maximum	84.6	5.8	3.6	7.8	17.1	1.8	
Average	**79.5**	**3.2**	**2.7**	**5.4**	**8.6**	**0.7**	**9**
Cowpea:							
Minimum	72.8	1.2	1.5	1.7	1.8	0.2	
Maximum	93.1	2.7	3.5	15.3	12.9	0.6	
Average	**83.6**	**1.7**	**2.4**	**4.8**	**7.1**	**0.4**	**10**
Soy bean:							
Minimum	63.6	1.8	2.2	4.8	5.8	0.5	
Maximum	81.5	5.1	5.9	9.7	16.0	1.6	
Average	**75.1**	**2.6**	**4.0**	**6.7**	**10.6**	**1.0**	**27**
Horse bean: Average	**85.1**	**1.4**	**3.0**	**4.3**	**5.7**	**0.5**	**4**
Flat pea (*Lathyrus sylvestris*): Average	**66.7**	**2.9**	**8.7**	**7.9**	**12.2**	**1.6**	**2**
Rape:							
Minimum	80.8	1.2	1.8	1.2	3.6	0.4	
Maximum	91.1	3.1	4.5	3.6	9.5	1.1	
Average	**85.7**	**2.0**	**2.4**	**2.2**	**7.1**	**0.6**	**10**

[1] Herd's grass of Pennsylvania.
[2] Meadow oat grass.
[3] Herd's grass of New England and New York.
[4] June grass.
[5] Swedish clover.
[6] Lucern.

Composition of feeding stuffs—Continued.

Feeding stuff.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Number of analyses.
SILAGE.							
Corn silage:	*Per ct.*	*Per ct*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Minimum	53.4	0.3	0.7	3.0	5.1	0.2	....
Maximum	87.7	3.3	3.6	10.5	24.2	2.0	....
Average	**77.3**	**1.4**	**1.9**	**5.9**	**12.6**	**0.9**	**161**
Recent analyses; corn more mature:							
Minimum	53.4	0.9	1.0	3.6	5.9	0.4	....
Maximum	87.6	2.7	3.1	9.9	30.6	2.0	....
Average	**74.4**	**1.5**	**2.2**	**5.8**	**15.0**	**1.1**	**62**
Sorghum silage:							
Minimum	71.9	0.8	0.6	5.9	13.8	0.1	....
Maximum	78.0	1.2	0.9	6.8	19.0	0.5	....
Average	**76.1**	**1.1**	**0.8**	**6.4**	**15.3**	**0.3**	**6**
Red clover silage:							
Minimum	61.4	1.9	3.0	5.1	8.1	0.9	....
Maximum	78.6	3.0	5.9	13.9	14.3	1.6	....
Average	**72.0**	**2.6**	**4.2**	**8.4**	**11.6**	**1.2**	**5**
Soy bean silage: Average	**74.2**	**2.8**	**4.1**	**9.7**	**6.9**	**2.2**	**1**
Cowpea vine silage: Average	**79.3**	**2.9**	**2.7**	**6.0**	**7.6**	**1.5**	**2**
Field pea vine silage: Average	**50.1**	**3.5**	**5.9**	**13.0**	**26.0**	**1.6**	**1**
Silage of mixture of cowpea vines and soy bean vines: Average	**69.8**	**4.5**	**3.8**	**9.5**	**11.1**	**1.3**	**1**
HAY AND DRY COARSE FODDER.							
Corn fodder,[1] field cured:							
Minimum	22.9	1.5	2.7	7.5	20.6	0.6	....
Maximum	60.2	5.5	6.9	24.7	47.8	2.5	....
Average	**42.2**	**2.7**	**4.5**	**14.3**	**34.7**	**1.6**	**35**
Corn leaves, field cured;							
Minimum	14.8	4.3	4.5	17.4	27.3	0.8	....
Maximum	44.0	7.4	8.3	27.4	41.4	2.2	....
Average	**30.0**	**5.5**	**6.0**	**21.4**	**35.7**	**1.4**	**17**
Corn husks, field cured:							
Minimum	26.7	0.6	1.3	6.8	14.3	0.5	....
Maximum	76.6	2.3	1.2	23.6	43.6	1.0	....
Average	**50.9**	**1.8**	**2.5**	**15.8**	**28.3**	**0.7**	**16**
Cornstalks, field cured:							
Minimum	51.3	0.6	1.2	6.9	11.2	0.3	....
Maximum	78.5	2.0	3.0	16.8	26.0	1.0	....
Average	**68.4**	**1.2**	**1.9**	**11.0**	**17.0**	**0.5**	**15**
Corn stover,[2] field cured:							
Minimum	15.4	1.7	1.8	14.1	23.3	0.7	....
Maximum	57.4	7.0	8.3	32.2	53.3	2.2	....
Average	**40.5**	**3.4**	**3.8**	**19.7**	**31.5**	**1.1**	**60**
Kafir corn stover, field cured: Average	**19.2**	**8.0**	**4.8**	**26.8**	**30.6**	**1.6**	**6**
Hay from:							
Barley—							
Minimum	6.4	4.2	8.0	21.0	44.9	2.4	....
Maximum	15.0	7.1	11.1	26.1	51.8	2.8	....
Average	**10.6**	**5.3**	**9.3**	**23.6**	**48.7**	**2.5**	**4**
Oats—							
Minimum	9.5	4.6	5.2	23.1	31.9	1.8	....
Maximum	26.5	9.4	9.5	30.9	48.5	3.3	....
Average	**16.0**	**6.1**	**7.4**	**27.2**	**40.6**	**2.7**	**12**
Redtop,[3] cut at different stages—							
Minimum	6.8	3.8	5.9	24.0	44.8	1.4	....
Maximum	11.6	7.0	10.4	31.8	50.4	3.2	....
Average	**8.9**	**5.2**	**7.9**	**28.6**	**47.5**	**1.9**	**9**
Redtop, cut in bloom—							
Minimum	6.8	4.8	7.8	24.0	46.8	1.5	....
Maximum	11.6	6.5	10.4	31.8	47.8	2.3	....
Average	**8.7**	**4.9**	**8.0**	**29.9**	**46.4**	**2.1**	**3**
Orchard grass—							
Minimum	6.5	5.0	6.6	28.9	32.9	1.7	....
Maximum	13.6	7.9	10.4	38.3	48.6	3.3	....
Average	**9.9**	**6.0**	**8.1**	**32.4**	**41.0**	**2.6**	**10**
Timothy,[4] all analyses—							
Minimum	6.1	2.5	3.8	22.2	34.3	1.0	....
Maximum	28.9	6.3	9.8	38.5	58.5	4.0	....
Average	**13.2**	**4.4**	**5.9**	**29.0**	**45.0**	**2.5**	**68**
Timothy, cut in full bloom—							
Minimum	7.0	2.5	5.0	22.2	34.4	2.0	....
Maximum	28.9	6.0	7.5	37.1	48.5	4.0	....
Average	**15.0**	**4.5**	**6.0**	**29.6**	**41.9**	**3.0**	**12**

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[1] Entire plant.

[2] What is left after the ears are harvested.

[3] Herd's grass of Pennsylvania.

[4] Herd's grass of New England and New York.

Composition of feeding stuffs—Continued.

Feeding stuff.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Number of analyses.
HAY AND DRY COARSE FODDER—cont'd.							
Hay from—Continued.							
Timothy cut soon after bloom—	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Minimum	7.8	3.5	4.6	25.7	37.0	1.7	....
Maximum	21.6	5.4	8.1	33.4	51.0	3.6	....
Average	**14.2**	**4.4**	**5.7**	**28.1**	**44.6**	**3.0**	**11**
Timothy cut when nearly ripe—							
Minimum	7.0	2.7	4.3	24.8	38.0	1.0	....
Maximum	22.7	5.1	6.0	38.5	49.1	2.8	....
Average	**14.1**	**3.9**	**5.0**	**31.1**	**43.7**	**2.2**	**12**
Kentucky blue grass—							
Minimum	14.3	4.5	5.3	17.7	31.8	2.0	....
Maximum	32.8	7.8	12.9	26.8	51.1	4.2	....
Average	**21.2**	**6.3**	**7.8**	**23.0**	**37.8**	**3.9**	**10**
Cut when seed was in milk—							
Minimum	22.5	5.6	6.0	23.9	33.2	3.4	....
Maximum	26.5	7.6	6.6	24.9	35.4	4.1	....
Average	**24.4**	**7.0**	**6.3**	**24.5**	**34.2**	**3.6**	**4**
Cut when seed was ripe—							
Minimum	23.7	5.1	5.3	20.4	33.6	2.8	....
Maximum	32.8	7.8	6.0	25.7	33.7	3.2	....
Average	**27.8**	**6.4**	**5.8**	**23.8**	**33.2**	**3.0**	**4**
Hungarian grass—							
Minimum	4.9	5.0	4.7	23.6	44.4	1.5	....
Maximum	9.5	7.5	12.3	36.3	53.0	3.5	....
Average	**7.7**	**6.0**	**7.5**	**27.7**	**49.0**	**2.1**	**13**
Meadow fescue—							
Minimum	7.4	5.5	4.5	20.8	28.5	1.6	....
Maximum	32.5	7.8	11.8	31.9	45.5	3.5	....
Average	**20.0**	**6.8**	**7.0**	**25.9**	**38.4**	**2.7**	**9**
Italian rye grass—							
Minimum	7.4	6.1	5.7	28.4	39.6	1.3	....
Maximum	9.3	7.9	8.8	33.9	48.9	1.9	....
Average	**8.5**	**6.9**	**7.5**	**30.5**	**45.0**	**1.7**	**4**
Mixed grasses—							
Minimum	6.5	2.1	4.8	21.0	33.4	1.3	....
Maximum	33.4	6.9	12.1	38.4	50.8	4.9	....
Average	**15.3**	**5.5**	**7.4**	**27.2**	**42.1**	**2.5**	**126**
Rowen (mixed)[1]—							
Minimum	8.2	5.1	9.6	20.1	33.6	2.2	....
Maximum	24.4	7.2	14.8	20.0	44.3	4.5	....
Average	**16.6**	**6.8**	**11.6**	**22.5**	**39.4**	**3.1**	**23**
Mixed grasses and clovers—							
Minimum	8.2	3.9	5.5	19.7	31.8	1.5	....
Maximum	15.9	9.6	14.4	35.1	48.9	3.1	....
Average	**12.9**	**5.5**	**10.1**	**27.6**	**41.3**	**2.6**	**17**
Swamp hay—							
Minimum	7.8	3.3	5.0	19.4	39.9	0.8	....
Maximum	17.9	12.1	8.8	31.6	51.7	3.6	....
Average	**11.6**	**6.7**	**7.2**	**26.6**	**45.9**	**2.0**	**8**
Salt marsh hay—							
Minimum	7.8	5.4	4.0	25.1	34.1	1.6	....
Maximum	18.6	11.8	7.8	33.8	54.3	3.1	....
Average	**10.4**	**7.7**	**5.5**	**30.0**	**44.1**	**2.4**	**10**
Red clover—							
Minimum	6.0	3.9	10.0	15.6	27.3	1.5	....
Maximum	31.3	8.3	20.2	35.7	52.2	5.9	....
Average	**15.3**	**6.2**	**12.3**	**24.8**	**38.1**	**3.3**	**38**
Red clover in bloom—							
Minimum	6.0	5.6	10.8	17.9	27.3	2.5	....
Maximum	31.3	8.3	15.4	28.1	41.3	5.9	....
Average	**20.8**	**6.6**	**12.4**	**21.9**	**33.8**	**4.5**	**6**
Alsike clover—							
Minimum	5.3	6.1	9.2	19.7	35.6	1.6	....
Maximum	13.9	12.2	16.1	29.5	45.9	4.2	....
Average	**9.7**	**8.3**	**12.8**	**25.6**	**40.7**	**2.9**	**9**
White clover—							
Minimum	6.1	4.5	13.9	20.3	33.4	1.7	....
Maximum	13.5	13.8	20.0	30.3	47.3	5.8	....
Average	**9.7**	**8.3**	**15.7**	**24.1**	**39.3**	**2.9**	**7**
Crimson clover—							
Minimum	5.9	7.4	13.6	20.1	29.3	1.5	....
Maximum	13.4	13.0	16.1	34.9	42.6	4.8	....
Average	**9.6**	**8.6**	**15.2**	**27.2**	**36.6**	**2.8**	**7**
Japan clover—							
Average	**11.0**	**8.5**	**13.8**	**24.0**	**39.0**	**3.7**	**2**
Vetch—							
Minimum	8.3	7.1	13.1	19.7	26.5	1.6	....
Maximum	15.8	11.6	23.1	28.1	40.2	3.0	....
Average	**11.3**	**7.9**	**17.0**	**25.4**	**36.1**	**2.3**	**5**

[1] Second cut.

Composition of feeding stuffs—Continued.

Feeding stuff.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Number of analyses.
HAY AND DRY COARSE FODDER—cont'd.							
Hay from—Continued.							
Serradella—	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Minimum	7.2	5.4	13.9	19.4	40.5	2.2	....
Maximum	11.7	10.3	16.6	22.9	46.0	2.9	....
Average	**9.2**	**7.2**	**15.2**	**21.6**	**44.2**	**2.6**	3
Alfalfa[1]—							
Minimum	4.6	3.1	10.2	14.0	35.1	1.1	....
Maximum	16.0	10.4	20.3	33.0	53.6	3.8	....
Average	**8.4**	**7.4**	**14.3**	**25.0**	**42.7**	**2.2**	21
Cowpea—							
Minimum	7.6	3.2	13.6	16.4	39.4	1.1	....
Maximum	14.0	10.2	20.3	26.0	49.5	3.7	....
Average	**10.7**	**7.5**	**16.6**	**20.1**	**42.2**	**2.9**	8
Soy bean—							
Minimum	6.1	4.8	14.0	17.3	31.8	2.4	....
Maximum	20.1	8.9	18.1	32.3	41.0	7.5	....
Average	**11.3**	**7.2**	**15.4**	**22.3**	**38.6**	**5.2**	6
Flat pea (*Lathyrus sylvestris*)—							
Minimum	6.3	6.5	17.6	18.5	27.7	1.6	....
Maximum	10.0	8.6	27.9	32.7	34.0	4.6	....
Average	**8.4**	**7.9**	**22.9**	**26.2**	**31.4**	**3.2**	5
Peanut vines (without nuts)—							
Minimum	6.3	7.3	9.1	18.3	33.1	1.7	....
Maximum	7.8	15.7	11.7	33.3	50.4	5.8	....
Average	**7.6**	**10.8**	**10.7**	**23.6**	**42.7**	**4.6**	6
Soy bean straw:							
Minimum	5.7	3.9	4.0	34.0	35.3	0.8	....
Maximum	14.0	4.9	4.9	49.6	43.3	3.2	....
Average	**10.1**	**5.8**	**4.6**	**40.4**	**37.4**	**1.7**	4
Horse bean straw: Average	**9.2**	**8.7**	**8.8**	**37.6**	**34.3**	**1.4**	1
Wheat straw:							
Minimum	6.5	3.0	2.9	34.3	31.0	0.8	....
Maximum	17.9	7.0	5.0	42.7	50.6	1.8	....
Average	**9.6**	**4.2**	**3.4**	**38.1**	**43.4**	**1.3**	7
Rye straw:							
Minimum	6.3	2.8	2.2	32.7	41.0	1.0	....
Maximum	9.7	3.4	3.6	43.3	52.9	1.6	....
Average	**7.1**	**3.2**	**3.0**	**38.9**	**46.6**	**1.2**	7
Oat straw:							
Minimum	6.5	3.7	2.7	31.8	33.5	1.7	....
Maximum	11.4	6.7	6.9	45.1	46.6	3.2	....
Average	**9.2**	**5.1**	**4.0**	**37.0**	**42.4**	**2.3**	12
Buckwheat straw:							
Minimum	9.0	4.9	3.3	37.2	32.1	0.7	....
Maximum	10.4	6.5	7.8	46.8	38.9	1.7	....
Average	**9.9**	**5.5**	**5.2**	**43.0**	**35.1**	**1.3**	3
ROOTS AND TUBERS.							
Potatoes:							
Minimum	75.4	0.8	1.1	0.3	14.1	....	....
Maximum	82.2	1.2	3.0	0.9	20.4	0.1	....
Average	**78.9**	**1.0**	**2.1**	**0.6**	**17.3**	**0.1**	12
Sweet potatoes:							
Minimum	66.0	0.7	0.5	0.6	18.0	0.3	....
Maximum	74.4	1.3	3.6	2.5	29.7	0.6	....
Average	**71.1**	**1.0**	**1.5**	**1.3**	**24.7**	**0.4**	6
Red beets:							
Minimum	85.8	0.7	1.1	0.6	3.8	0.1	....
Maximum	92.2	1.6	1.8	1.7	11.3	0.3	....
Average	**88.5**	**1.0**	**1.5**	**0.9**	**8.0**	**0.1**	9
Sugar beets:							
Minimum	80.5	0.4	0.4	0.5	5.7	0.1	....
Maximum	90.8	1.4	3.2	1.3	14.7	0.4	....
Average	**86.7**	**0.8**	**1.5**	**0.9**	**9.9**	**0.1**	28
Mangel-wurzels:							
Minimum	86.9	0.8	1.0	0.6	2.4	0.0	....
Maximum	94.4	1.4	1.9	1.3	8.7	0.7	....
Average	**91.2**	**1.0**	**1.4**	**0.8**	**5.4**	**0.2**	16
Turnips:							
Minimum	87.2	0.7	0.8	0.8	4.2	0.04	....
Maximum	92.4	1.0	1.7	1.4	8.8	0.2	....
Average	**90.6**	**0.8**	**1.3**	**1.2**	**5.9**	**0.2**	4
Ruta-bagas:							
Minimum	87.1	1.0	1.0	1.1	5.1	0.1	....
Maximum	91.8	1.4	1.3	1.4	9.1	0.3	....
Average	**88.6**	**1.2**	**1.2**	**1.3**	**7.5**	**0.2**	4

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[1] Lucern.

Composition of feeding stuffs—Continued.

Feeding stuff.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Number of analyses.
ROOTS AND TUBERS—continued.							
Carrots:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Minimum	86.5	1.6	0.8	0.9	5.1	0.2	....
Maximum	91.1	1.3	2.0	2.3	10.4	0.7	....
Average	**88.6**	**1.0**	**1.1**	**1.3**	**7.6**	**0.4**	**8**
Artichokes:							
Minimum	75.7	1.2	2.0	0.7	15.9	0.1	....
Maximum	79.7	3.7	2.6	1.1	18.1	0.2	....
Average	**78.0**	**1.8**	**2.4**	**0.9**	**16.8**	**0.1**	**7**
GRAINS AND OTHER SEEDS.							
Corn, kernel:							
Dent, all analyses—							
Minimum	6.2	1.0	7.5	0.9	65.9	3.1	....
Maximum	19.4	2.6	11.8	4.8	75.7	7.5	....
Average	**10.6**	**1.5**	**10.3**	**2.2**	**70.4**	**5.0**	**86**
Flint, all analyses—							
Minimum	4.5	1.0	7.0	0.7	65.0	3.4	....
Maximum	19.6	1.9	13.7	2.9	76.7	7.1	....
Average	**11.3**	**1.4**	**10.5**	**1.7**	**70.1**	**5.0**	**68**
All varieties and analyses—							
Minimum	4.5	1.0	7.0	0.7	61.8	3.1	....
Maximum	20.7	2.6	15.3	5.2	76.7	9.3	....
Average	**10.9**	**1.5**	**10.5**	**2.1**	**69.6**	**5.4**	**208**
Kafir corn, kernel: Average	**12.5**	**1.3**	**10.9**	**1.9**	**70.5**	**2.9**	**6**
Sorghum seed:							
Minimum	9.3	1.4	7.7	1.5	59.0	2.1	....
Maximum	16.8	4.3	11.3	8.7	73.6	4.6	....
Average	**12.8**	**2.1**	**9.1**	**2.6**	**69.8**	**3.6**	**10**
Barley:							
Minimum	7.2	1.8	8.6	1.3	66.7	1.5	....
Maximum	12.6	3.2	15.7	4.2	73.9	3.2	....
Average	**10.9**	**2.4**	**12.4**	**2.7**	**69.8**	**1.8**	**10**
Oats:							
Minimum	8.9	2.0	8.0	1.5	53.5	3.4	....
Maximum	13.5	4.0	14.4	12.9	66.9	5.8	....
Average	**11.0**	**3.0**	**11.8**	**9.5**	**59.7**	**5.0**	**30**
Rye:							
Minimum	8.7	1.8	9.5	1.4	71.2	1.4	....
Maximum	13.2	1.9	12.1	2.1	73.9	2.1	....
Average	**11.6**	**1.9**	**10.6**	**1.7**	**72.5**	**1.7**	**6**
Wheat, spring varieties:							
Minimum	8.1	1.5	8.4	1.3	66.1	1.8	....
Maximum	13.4	2.6	15.4	2.3	74.9	2.6	....
Average	**10.4**	**1.9**	**12.5**	**1.8**	**71.2**	**2.2**	**13**
Wheat, winter varieties, all analyses:							
Minimum	7.1	0.8	8.1	0.4	66.7	1.3	....
Maximum	14.0	3.6	16.6	2.9	77.7	3.9	....
Average	**10.5**	**1.8**	**11.8**	**1.8**	**72.0**	**2.1**	**262**
Wheat, all varieties:							
Minimum	7.1	0.8	8.1	0.4	64.8	1.3	....
Maximum	14.0	3.6	17.2	3.1	77.7	3.9	....
Average	**10.5**	**1.8**	**11.9**	**1.8**	**71.9**	**2.1**	**310**
Rice:							
Minimum	11.4	0.3	5.9	0.1	77.5	0.3	....
Maximum	14.0	0.5	8.6	0.4	80.6	0.6	....
Average	**12.4**	**0.4**	**7.4**	**0.2**	**79.2**	**0.4**	**10**
Buckwheat.							
Minimum	10.9	1.6	8.6	7.8	62.6	2.2	....
Maximum	14.8	2.3	11.0	9.4	65.4	2.4	....
Average	**12.6**	**2.0**	**10.0**	**8.7**	**64.5**	**2.2**	**8**
Sunflower seed (whole):							
Minimum	8.5	2.1	15.8	29.5	22.0	20.9	....
Maximum	8.8	3.2	16.7	30.3	20.7	21.5	....
Average	**8.6**	**2.6**	**16.3**	**29.9**	**21.4**	**21.2**	**2**
Cotton seed, whole (with hulls):							
Minimum	5.8	2.9	14.5	10.9	17.3	15.3	....
Maximum	17.5	5.0	21.7	28.7	36.4	22.5	....
Average	**9.1**	**4.0**	**19.6**	**18.9**	**28.3**	**20.1**	**11**
Peanut kernel (without hulls):							
Minimum	4.9	1.9	23.2	2.0	12.7	35.0	....
Maximum	13.2	3.8	31.5	18.4	19.1	47.4	....
Average	**7.5**	**2.4**	**27.9**	**7.0**	**15.6**	**39.6**	**7**
Soy bean:							
Minimum	2.8	3.1	26.3	2.2	23.3	12.3	....
Maximum	19.3	12.4	41.8	8.3	35.3	20.8	....
Average	**8.7**	**5.4**	**36.3**	**3.9**	**27.7**	**18.0**	**44**

Composition of feeding stuffs—Continued.

Feeding stuff.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Number of analyses.
GRAINS AND OTHER SEEDS—continued.							
Cowpea:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Minimum	9.6	2.9	19.3	2.5	50.5	1.3	....
Maximum	20.9	4.0	26.4	5.0	62.0	2.7	....
Average	**11.9**	**3.4**	**23.5**	**3.8**	**55.7**	**1.7**	17
MILL PRODUCTS.							
Corn meal:							
Minimum	8.0	0.9	7.1	0.5	60.4	2.0	....
Maximum	27.4	4.1	13.9	3.1	74.0	5.1	....
Average	**15.0**	**1.4**	**9.2**	**1.9**	**68.7**	**3.8**	77
Corn and cob meal:							
Minimum	9.5	1.2	5.8	4.7	56.8	2.5	....
Maximum	26.3	1.9	12.2	9.4	69.7	4.7	....
Average	**15.1**	**1.5**	**8.5**	**6.6**	**64.8**	**3.5**	7
Barley meal:							
Minimum	9.9	1.6	9.8	5.9	63.5	1.5	....
Maximum	13.6	3.8	12.7	7.0	68.0	3.2	....
Average	**11.9**	**2.6**	**10.5**	**6.5**	**66.3**	**2.2**	3
Rye flour:							
Minimum	12.4	0.6	6.0	0.4	77.6	0.8	....
Maximum	13.6	0.8	6.9	0.5	79.1	0.9	....
Average	**13.1**	**0.7**	**6.7**	**0.4**	**78.3**	**0.8**	4
Pea meal:							
Minimum	8.9	2.6	19.1	11.1	50.2	0.9	....
Maximum	12.1	2.7	21.4	17.7	52.0	1.5	....
Average	**10.5**	**2.6**	**20.2**	**14.4**	**51.1**	**1.2**	2
Soy-bean meal	**10.2**	**5.0**	**35.9**	**3.4**	**28.0**	**17.5**	4
Ground corn and oats, equal parts:							
Minimum	10.7	1.9	8.4	....	[1]70.4	4.0	....
Maximum	13.1	2.7	10.4	....	[1]73.7	5.0	....
Average	**11.9**	**2.2**	**9.6**	....	**[1]72.0**	**4.4**	6
WASTE PRODUCTS.							
Corncob:							
Minimum	7.2	0.7	1.2	18.2	43.8	0.1	....
Maximum	24.8	2.7	3.7	38.3	66.7	0.9	....
Average	**10.7**	**1.4**	**2.4**	**30.1**	**54.9**	**0.5**	18
Hominy chop:							
Minimum	8.1	1.9	7.9	2.5	61.0	4.5	....
Maximum	13.5	3.1	11.2	6.7	71.1	11.2	....
Average	**11.1**	**2.5**	**9.8**	**3.8**	**64.5**	**8.3**	12
Corn bran:							
Minimum	7.1	0.8	7.7	7.8	57.2	4.0	....
Maximum	12.3	2.4	11.8	14.3	68.9	8.5	....
Average	**8.7**	**1.5**	**9.8**	**11.2**	**62.6**	**6.2**	6
Corn germ:							
Minimum	9.4	1.9	9.7	1.9	61.9	5.2	....
Maximum	13.0	7.4	9.9	5.8	67.4	11.2	....
Average	**10.7**	**4.0**	**9.8**	**4.1**	**64.0**	**7.4**	3
Corn-germ meal:							
Minimum	6.5	0.8	10.0	7.8	57.4	4.3	....
Maximum	9.9	2.6	14.0	13.0	67.0	11.2	....
Average	**8.1**	**1.3**	**11.1**	**9.9**	**62.5**	**7.1**	6
Gluten meal:							
Miscellaneous—							
Minimum	4.5	0.5	10.3	0.3	32.4	1.7	....
Maximum	12.3	2.0	49.1	9.3	62.7	20.0	....
Average	**8.6**	**0.8**	**30.0**	**2.6**	**49.2**	**8.8**	67
Buffalo, average	**8.2**	**0.9**	**24.5**	**6.1**	**47.8**	**12.5**	7
Chicago—							
Minimum	5.5	0.6	29.2	1.1	37.0	1.0	....
Maximum	17.2	2.3	43.1	6.3	52.6	9.6	....
Average	**9.5**	**1.2**	**37.6**	**2.3**	**44.4**	**5.0**	42
Hammond, average	**8.1**	**1.0**	**28.3**	**1.1**	**50.8**	**10.7**	5
King—							
Minimum	3.0	0.4	26.3	1.2	33.2	2.8	....
Maximum	9.5	1.9	37.2	2.4	55.0	19.8	....
Average	**7.2**	**1.4**	**34.2**	**1.7**	**39.0**	**16.5**	14
Cream gluten:							
Minimum	7.7	0.6	34.1	1.2	35.0	13.6	....
Maximum	9.0	0.8	38.2	1.3	41.1	15.8	....
Average	**8.1**	**0.7**	**36.1**	**1.3**	**39.0**	**14.8**	3
Recent analyses—							
Minimum	8.8	0.5	32.1	1.3	47.7	1.7	....
Maximum	11.2	1.0	35.9	2.5	52.3	3.8	....
Average	**9.6**	**0.9**	**34.6**	**1.9**	**50.4**	**2.6**	7

[1] Including fiber.

Composition of feeding stuffs—Continued.

Feeding stuff.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Number of analyses.
WASTE PRODUCTS—continued.							
Gluten feed:							
Miscellaneous—	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Minimum	4.4	0.6	14.8	1.3	44.5	3.0	....
Maximum	12.5	3.4	28.3	11.1	61.8	15.0	....
Average	**7.8**	**1.1**	**23.4**	**6.2**	**53.2**	**8.3**	42
Recent analyses—							
Minimum	5.4	0.6	14.8	1.3	48.5	3.0	....
Maximum	10.4	3.4	28.3	11.1	60.6	11.5	....
Average	**8.1**	**1.3**	**23.2**	**6.4**	**54.7**	**6.3**	20
Buffalo—							
Minimum	7.4	0.8	19.5	2.5	44.6	2.3	....
Maximum	10.5	3.7	28.6	9.6	59.5	14.3	....
Average	**8.6**	**1.8**	**24.6**	**6.7**	**50.0**	**8.3**	52
Recent analyses—							
Minimum	7.6	0.8	21.3	2.5	49.3	2.3	....
Maximum	10.3	4.1	28.6	7.9	59.5	4.7	....
Average	**9.0**	**2.7**	**26.6**	**6.3**	**52.0**	**3.4**	22
Davenport—							
Minimum	7.6	0.9	22.9	5.5	44.6	2.5	....
Maximum	10.1	1.7	34.9	7.5	56.7	6.4	....
Average	**8.6**	**1.3**	**26.3**	**6.6**	**52.9**	**4.3**	6
Glen Cove—							
Minimum	8.2	0.4	27.1	3.8	51.9	2.9	....
Maximum	9.6	0.7	29.7	4.5	56.0	4.1	....
Average	**8.9**	**0.6**	**28.8**	**4.2**	**53.8**	**3.7**	4
Pope's	**14.0**	**0.6**	**33.3**	**1.6**	**36.5**	**14.1**	1
Rockford (Diamond)—							
Minimum	7.2	0.6	20.0	5.8	49.3	3.2	....
Maximum	9.9	7.9	30.1	8.5	59.8	10.2	....
Average	**8.7**	**1.4**	**23.7**	**6.8**	**54.9**	**4.5**	13
Waukegan—							
Minimum	6.2	1.0	24.3	5.9	50.9	3.5	....
Maximum	9.1	1.2	27.7	7.5	56.3	4.6	....
Average	**8.3**	**1.1**	**26.5**	**6.9**	**53.2**	**4.0**	5
Chicago maize feed:							
Minimum	8.5	0.7	19.3	6.7	48.7	5.6	....
Maximum	9.7	1.4	26.9	8.7	56.1	8.3	....
Average	**9.1**	**1.0**	**23.6**	**7.4**	**51.7**	**7.2**	5
Glucose feed and glucose refuse: Average	**6.5**	**1.1**	**20.7**	**4.5**	**56.8**	**10.4**	2
Dried starch feed and sugar feed:							
Minimum	9.2	0.6	17.1	3.1	49.2	7.3	....
Maximum	11.7	1.2	22.1	5.6	59.6	11.1	....
Average	**10.9**	**0.9**	**19.7**	**4.7**	**54.8**	**9.0**	4
Starch feed, wet:							
Minimum	62.3	0.1	3.6	1.6	18.7	1.3	....
Maximum	72.2	0.6	9.6	4.4	28.9	4.4	....
Average	**65.4**	**0.3**	**6.1**	**3.1**	**22.0**	**3.1**	12
Oat feed:							
Minimum	6.4	3.2	12.6	3.7	56.2	6.1	....
Maximum	9.2	4.2	20.0	12.5	63.7	7.8	....
Average	**7.7**	**3.7**	**16.0**	**6.1**	**59.4**	**7.1**	4
Barley screenings:							
Minimum	12.0	3.5	12.1	7.0	61.6	2.6	....
Maximum	12.4	3.6	12.5	7.6	62.0	2.9	....
Average	**12.2**	**3.6**	**12.3**	**7.3**	**61.8**	**2.8**	2
Malt sprouts:							
Minimum	7.3	3.8	21.0	9.3	45.5	1.0	....
Maximum	12.0	6.7	25.9	12.0	50.3	3.0	....
Average	**10.2**	**5.7**	**23.2**	**10.7**	**48.5**	**1.7**	4
Brewers' grains, wet:							
Minimum	68.6	0.3	4.3	3.1	9.6	0.8	....
Maximum	79.4	1.5	6.9	5.6	15.9	2.8	....
Average	**75.7**	**1.0**	**5.4**	**3.8**	**12.5**	**1.6**	15
Brewers' grains, dried:							
Minimum	6.2	2.4	19.3	10.2	37.4	4.2	....
Maximum	11.9	5.6	31.8	15.8	56.8	8.4	....
Average	**8.0**	**3.4**	**24.1**	**13.0**	**44.8**	**6.7**	15
Distillery grains (dried), principally corn:							
Minimum	5.0	1.1	24.9	8.9	32.2	7.8	....
Maximum	8.7	3.4	35.5	13.7	46.0	22.2	....
Average	**7.0**	**2.0**	**29.2**	**11.0**	**39.4**	**11.4**	12
Distillery grains (dried), principally rye: Average	**6.8**	**2.1**	**17.3**	**12.3**	**54.0**	**7.5**	3
Grano gluten: Average	**5.9**	**2.7**	**31.0**	**11.4**	**34.8**	**14.2**	3
Atlas gluten meal: Average	**7.2**	**2.4**	**31.3**	**11.0**	**35.3**	**12.8**	3
Atlas gluten feed: Average	**7.4**	**1.7**	**31.1**	**11.0**	**36.3**	**12.5**	11
Rye bran:							
Minimum	8.2	2.9	11.5	2.5	59.8	1.7	....
Maximum	13.7	4.5	16.8	4.1	67.6	4.9	....
Average	**11.8**	**3.5**	**14.7**	**3.3**	**63.9**	**2.8**	11

Composition of feeding stuffs—Continued.

Feeding stuff.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Number of analyses.
WASTE PRODUCTS—continued.							
Wheat bran from spring wheat:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Minimum	7.4	4.0	14.3	5.4	51.7	3.6	....
Maximum	13.6	6.0	18.1	10.1	58.1	5.0	....
Average	**11.5**	**5.4**	**16.1**	**8.0**	**54.5**	**4.5**	10
Wheat bran from winter wheat:							
Minimum	10.6	5.0	13.9	7.2	50.5	3.5	....
Maximum	13.6	6.4	17.8	8.9	56.2	4.5	....
Average	**12.3**	**5.9**	**16.0**	**8.1**	**53.7**	**4.0**	7
Wheat bran, all analyses:							
Minimum	7.4	2.5	12.1	2.4	45.5	1.5	....
Maximum	15.8	7.8	18.9	15.5	63.2	7.0	....
Average	**11.9**	**5.8**	**15.4**	**9.0**	**53.9**	**4.0**	88
Wheat middlings:							
Minimum	9.2	1.4	10.1	1.3	53.0	2.1	....
Maximum	16.0	6.3	20.0	12.7	70.9	5.9	....
Average	**12.1**	**3.3**	**15.6**	**4.6**	**60.4**	**4.0**	32
Wheat shorts:							
Minimum	4.1	2.0	11.1	6.0	50.0	2.5	....
Maximum	15.5	6.2	19.4	10.5	67.0	6.1	....
Average	**11.8**	**4.6**	**14.9**	**7.4**	**56.8**	**4.5**	12
Wheat screenings:							
Minimum	7.8	1.9	8.3	1.7	61.0	2.7	....
Maximum	13.6	3.8	16.9	7.5	70.4	3.3	....
Average	**11.6**	**2.9**	**12.5**	**4.9**	**65.1**	**3.0**	10
Rice bran:							
Minimum	8.8	8.4	10.9	2.0	41.9	5.2	....
Maximum	10.7	12.4	13.6	17.8	62.3	10.9	....
Average	**9.7**	**10.0**	**12.1**	**9.5**	**49.9**	**8.8**	5
Rice hulls:							
Minimum	7.7	10.5	2.9	30.3	36.0	0.6	....
Maximum	8.5	15.1	4.7	38.6	41.6	0.9	....
Average	**8.2**	**13.2**	**3.6**	**35.7**	**38.6**	**0.7**	3
Rice polish:							
Minimum	9.0	2.8	10.9	2.4	45.5	6.5	....
Maximum	11.2	11.3	12.9	14.5	63.3	8.0	....
Average	**10.0**	**6.7**	**11.7**	**6.3**	**58.0**	**7.3**	4
Buckwheat bran:							
Minimum	9.1	4.1	21.6	4.3	36.4	5.4	....
Maximum	12.1	5.4	31.4	20.3	42.3	8.9	....
Average	**11.5**	**4.5**	**24.8**	**11.7**	**40.8**	**6.7**	7
Buckwheat middlings:							
Minimum	7.5	4.2	24.8	2.4	36.3	5.7	....
Maximum	16.3	6.2	35.9	12.9	52.7	9.2	....
Average	**11.8**	**4.8**	**28.0**	**6.3**	**41.9**	**7.2**	12
Cotton-seed feed:							
Minimum	6.2	3.2	10.7	19.6	36.4	2.4	....
Maximum	9.7	4.4	22.6	37.4	42.0	6.0	....
Average	**8.0**	**3.7**	**13.4**	**32.5**	**38.7**	**3.7**	5
Cotton-seed meal:							
Minimum	5.8	5.7	23.3	1.3	15.7	8.8	....
Maximum	18.5	8.8	50.8	10.1	38.7	18.0	....
Average	**8.2**	**7.2**	**42.3**	**5.6**	**23.6**	**13.1**	35
Cotton-seed hulls:							
Minimum	9.2	1.8	2.2	37.9	12.4	0.6	....
Maximum	16.7	4.4	5.4	67.0	41.8	5.4	....
Average	**11.1**	**2.8**	**4.2**	**46.3**	**33.4**	**2.2**	20
Linseed meal, old process:							
Minimum	5.6	4.6	27.7	4.7	28.4	5.2	....
Maximum	12.4	8.2	38.2	12.9	41.9	11.6	....
Average	**9.2**	**5.7**	**32.9**	**8.9**	**35.4**	**7.9**	21
Linseed meal, new process:							
Minimum	6.0	4.9	27.1	5.9	32.1	1.3	....
Maximum	13.4	6.9	44.0	10.2	48.0	4.8	....
Average	**9.9**	**5.6**	**35.9**	**8.8**	**36.8**	**3.0**	33
Peanut meal:[1]							
Minimum	6.6	3.7	37.5	2.5	28.5	5.8	....
Maximum	15.4	5.5	52.4	7.4	30.8	17.5	....
Average	**10.7**	**4.9**	**47.6**	**5.1**	**23.7**	**8.0**	2,480
Peanut hulls							
Minimum	7.8	1.9	4.6	56.5	9.7	0.9	....
Maximum	10.8	4.6	8.6	72.3	18.9	2.0	....
Average	**9.0**	**3.4**	**6.6**	**64.3**	**15.1**	**1.6**	5

[1] Mostly European analyses.

Composition of feeding stuffs—Continued.

Feeding stuff.	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Number of anaylses.
WASTE PRODUCTS—continued.							
Sugar-beet pulp:							
Fresh—	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Minimum	88.5	0.1	0.6	1.9	5.4	0.1	....
Maximum	91.7	0.7	1.4	2.6	7.2	0.6	....
Average	**89.9**	**0.4**	**1.0**	**2.2**	**6.3**	**0.2**	7
Dry—							
Minimum	3.6	2.7	8.7	17.3	56.4	0.7	....
Maximum	10.8	4.1	12.1	22.4	59.6	1.7	....
Average	**6.4**	**3.3**	**10.8**	**19.8**	**58.4**	**1.3**	3
MILK AND ITS BY-PRODUCTS.							
Whole milk:							
Minimum	80.3	0.4	2.1	....	2.1	1.7	....
Maximum	90.7	1.2	6.4	....	6.1	6.5	....
Average	**87.2**	**0.7**	**3.6**	....	**4.9**	**3.7**	793
Skim milk, cream raised by setting:							
Minimum	88.3	0.5	2.6	....	3.8	0.2	....
Maximum	92.6	1.0	3.9	....	5.5	2.5	....
Average	**90.4**	**0.7**	**3.3**	....	**4.7**	**0.9**	96
Skim milk, cream raised by separator:							
Minimum	89.8	....	....	....	....	....	....
Maximum	91.2	....	....	....	....	....	....
Average	**90.6**	**0.7**	**3.2**	....	**5.2**	**0.3**	9
Buttermilk:							
Minimum	82.2	0.4	1.7	....	2.5	....	....
Maximum	93.3	0.9	6.2	....	5.6	5.4	....
Average	**91.0**	**0.7**	**3.0**	....	**4.8**	**0.5**	85
Whey:							
Minimum	93.2	0.3	0.3	....	4.4	0.0	....
Maximum	94.6	0.6	1.2	....	5.8	0.2	....
Average	**93.8**	**0.4**	**0.6**	....	**5.1**	**0.1**	46
POULTRY FOODS.							
Animal meal:							
Minimum	2.38	33.39	25.20	....	....	7.26	....
Maximum	8.38	43.54	48.53	....	....	21.80	....
Average	**5.67**	**39.88**	**39.42**	....	....	**10.73**	35
Meat or beef scrap:							
Minimum	5.40	11.72	36.69	....	....	12.31	....
Maximum	12.59	21.70	66.81	....	....	30.90	....
Average	**7.86**	**17.39**	**49.72**	....	....	**18.51**	33
Meat or beef meal:							
Minimum	6.08	....	35.10	....	....	6.83	....
Maximum	6.44	....	66.20	....	....	19.50	....
Average	**6.27**	....	**48.36**	....	....	**12.90**	14
Meat and bone:							
Minimum	3.79	....	24.22	....	....	5.89	....
Maximum	9.74	....	58.71	....	....	13.06	....
Average	**5.68**	....	**36.66**	....	....	**10.49**	7
Bone meal (Bowker's)	....	....	**34.00**	....	....	**2.20**	....
Fresh bone	**34.20**	**22.80**	**20.60**	....	**1.90**	**20.50**	....
Cut bone	**26.29**	**15.85**	**15.20**	....	....	**23.13**	....
Boiled beef bone:							
Minimum	4.10	....	40.76	....	....	11.44	....
Maximum	8.16	....	48.09	....	....	18.70	....
Average	**5.68**	....	**44.75**	....	....	**17.11**	5
Clover meal: Average	**7.77**	....	**10.51**	....	....	**1.86**	3
H. O. Poultry Food:							
Minimum	6.66	2.52	15.00	2.86	60.46	4.67	....
Maximum	10.80	3.01	17.88	5.13	64.35	6.36	....
Average	**8.49**	**2.64**	**16.83**	**4.56**	**62.01**	**5.47**	20
American Poultry Food:							
Minimum	7.22	2.67	8.31	4.33	60.49	4.82	....
Maximum	11.15	2.95	15.53	7.20	63.47	7.40	....
Average	**9.16**	**2.81**	**13.22**	**5.48**	**63.18**	**6.15**	24

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Feb, 8, 1895

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FOODS: NUTRITIVE VALUE AND COST.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., October 23, 1894.

Sir: I have the honor to transmit herewith, for publication as a Farmers' Bulletin, an article on the nutritive value and pecuniary economy of foods, prepared by Prof. W. O. Atwater, ph. d., of Wesleyan University, special agent in charge of food investigations. This article has been prepared under that clause of the act of Congress making appropriations for this Department for the current fiscal year which provides funds "to enable the Secretary of Agriculture to investigate and report upon the nutritive value of the various articles and commodities used for human food," with suggestions of less wasteful and more economical dietaries than those in common use. As this is the first of a series of popular bulletins on the nutritive value and economy of food which this Office intends to prepare, it has been deemed wise to confine its scope to a careful definition of technical terms, tables and explanations showing the nutritive value of common food materials and the ways in which they may be combined in dietaries on the basis of their actual value as food, and some general considerations concerning the pecuniary economy of food, with suggestions regarding wastes to be avoided. There are of course great difficulties in the way of the clear and accurate popular presentation of the results of scientific research on so complex a subject as human nutrition, but it is believed that a careful perusal of this bulletin will at least enable the reader to see the relation between the nutritive value and the cost of foods, and will greatly aid him in understanding the discussion of other phases of this subject in succeeding bulletins.

Respectfully,

A. C. True,
Director.

Hon. Chas. W. Dabney, Jr.,
Acting Secretary.

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FOODS: NUTRITIVE VALUE AND COST.

THE NUTRIMENT IN FOOD AND HOW IT IS USED IN THE BODY.

A quart of milk, three-quarters of a pound of moderately fat beef, sirloin steak for instance, and five ounces of wheat flour, all contain about the same amount of nutritive material; but we pay different prices for them and they have different values for nutriment. The milk comes nearest to being a perfect food. It contains all of the different kinds of nutritive materials that the body needs. Bread made from the wheat flour will support life. It contains all of the necessary ingredients for nourishment, but not in the proportions best adapted for ordinary use. A man might live on beef alone, but it would be a very one-sided and imperfect diet. But meat and bread together make the essentials of a healthful diet. Such are the facts of experience. The advancing science of later years explains them. This explanation takes into account, not simply quantities of meat and bread and milk and other materials which we eat, but also the nutritive ingredients or "nutrients" which they contain.

CHEMICAL COMPOSITION OF FOOD MATERIALS—QUANTITIES OF NUTRIENTS.

Edible portion and refuse.—If the reader will take the pains to notice the next piece of beef that he has to carve for dinner he will observe, first of all, that along with the meat which is good to eat there is more or less of bone, which, except in so far as it may be used for soup, is of no value for food. If, however, the meat man has already cut out the bone, only the edible portion will be left. Beef, then, consists of edible portion and refuse. The same is true of fish, in which the bones and entrails and sometimes the skin are the refuse. In eggs there is a corresponding distinction between the shells and the so-called "meat." The inside of the potato and the wheat flour are the edible portion, and the skin and bran are the refuse of the potato and wheat.

If we weigh the whole meat, bone and all, to start with, and afterward weigh bone and meat separately, we can easily calculate the percentages of refuse and edible portion. The proportions of refuse are from 8 to 10 per cent in a round of beef, about 14 per cent in eggs, 18 per cent in a leg of mutton, 40 per cent in chicken, and 50 per cent or more in some kinds of fish. In such food materials as milk, flour, and bread there is of course no refuse.

Water and nutrients.—Meat freed from bone, milk, and flour all contain more or less water. This can be dried out by heating, as is done in the chemical analysis of food materials. The proportions of water in different food materials vary greatly. Ordinary flour contains about 12½ per cent, or one-eighth. The fatter kinds of meat have from 15 to 50 per cent and the leaner meats from 50 to 75 per cent of water. One-third of the weight of bread and three-fourths of the weight of potatoes consist of water. The water in all these substances is precisely the same as any other water and has no more value for nutriment.

The material which remains in the edible portion of the food after removal of the water is called by chemists "water-free substance." It includes all of the actually nutritive ingredients or nutrients of the food. The nutrients are of several kinds. They are commonly divided into four classes called protein, fats, carbohydrates, and mineral matters. Water permeates all parts of the body and is indispensable for nourishment, but the water of the food is not transformed in the body as are the protein, fats, and carbohydrates, and it is not usually taken into account in estimates of nutritive value.

Protein.—Meat consists of lean and fat. Part of the fat is in large lumps, which can be easily separated from the lean. Indeed, we often cut out the fat of the meat which is served on our plates at the table and reject it. But a portion of the fat is in very fine particles diffused throughout the lean. Much of this finely divided fat is in particles so small as to be invisible to the naked eye, but it is possible to separate them very completely from the lean by processes of analysis common in the laboratory. After the water and the fat have been removed from the lean meat, the material which remains will contain a little mineral matter, which would be left as ash if it were burned; the rest consists chiefly of so called protein compounds. The protein is the chief nutritive constituent of fish and eggs as well as of lean meat. The albumen and casein of milk are also protein compounds. The gluten of wheat consists of protein compounds. These compounds occur in corn, beans, potatoes, and indeed all kinds of vegetable foods.

One trouble in speaking of these substances is that they are known by so many different names. The terms "nitrogenous compounds," "albuminoids," and "proteids" are often applied to them. The first term is very proper, because the protein compounds contain the element nitrogen, which is not found in the other classes of nutrients. The term "albuminoids" comes from albumen, a substance familiar to us in the white of egg, and is applied to the compounds which are similar to albumen. Some writers prefer the word "proteids" for substances of this class.

Along with the muscle the meat contains tendon and cartilage, which are familiarly called gristle. These materials and the ossein, or "animal matter" of bone, are very similar to gelatin (glue), and are changed to gelatin on heating with water. They are hence termed gelatinoids. The gelatinoids are the principal ingredients of tendon and similar tissues, while the albuminoids are the chief ingredients of muscle.

There is still another class of nitrogenous substances in meat, which, though small in quantity, are very interesting. They are known in the chemical laboratory as creatin, creatinin, carnin, etc., and are grouped together as "extractives," because they are extracted from flesh by water. They are the chief constituents of beef tea and most meat extracts.

The albuminoids and gelatinoids may be properly grouped together as proteids. It is customary to use the term protein to include albuminoids, gelatinoids, and extractives.

Fat.—Fat is familiar to us in meat, from which we get it in the form of tallow and lard; in milk, from which it is obtained as butter; and in the various vegetable oils, such as olive oil, cotton-seed oil, and the oils of wheat and corn. Larger or smaller proportions of fat are found in most food materials.

Carbohydrates.—Potatoes, wheat, and corn contain large proportions of starch. Sugar cane and sorghum are rich in sugar. Starch and sugar are very similar in chemical composition and are called carbohydrates. Other carbohydrates are found in animals and plants, such as glycogen or "animal starch," which is found in the liver, and cellulose, which occurs in plants.

Ash.—The mineral matter, or ash, which is left behind when animal or vegetable matter is burned, consists of a variety of chemical compounds commonly called salts, and includes phosphates, sulphates, and chlorides of the metals, calcium, magnesium, potassium, and sodium. Calcium phosphate, or phosphate of lime, is the chief mineral constituent of bone. Common salt is chloride of sodium.

These substances are separated from each other in the laboratory by various methods of analysis. The everyday handling of food materials also involves crude processes of analysis.

We let milk stand; the globules of fat rise in cream, still mingled, however, with water, protein, carbohydrates, and mineral salts. To separate the other ingredients from the fat, the cream is churned. The more perfect this separation—i. e., the more accurate the analysis—the better will be the butter. Put a little rennet into the skimmed milk and the casein, called in chemical language an albuminoid or protein compound, will be curdled and may be freed from the bulk of the water, sugar, and other ingredients by the cheese press. To separate milk sugar, a carbohydrate, from the whey is a simple matter. One may see it done by Swiss shepherds in their Alpine huts. But farmers find it more profitable to put it in the pigpen, the occupants of which are endowed with the happy faculty of transforming the sugar, starch, and other carbohydrates of their food into the fat of pork.

The farm boy who on cold winter mornings goes to the barn to feed the cattle, and solaces himself by taking grain from the wheat bin and chewing it into what he calls "wheat gum," makes, unknowingly, a rough sort of analysis of the wheat. With the crushing of the grain and the action of saliva in his mouth the starch, sugar, and other carbohydrates are separated. Some of the fat, i. e., oil, is also removed, and finds its way with the carbohydrates into the stomach. The tenacious gluten, which contains the albuminoids or protein and constitutes what he calls the gum, is left. When, in the natural order of events, the cows are cared for and the gum is swallowed, its albuminoids enter upon a round of transformation in the boy's body, in the course of which they are changed into other forms of protein, such as albumen of blood or myosin of muscle; or are consumed with the oil and sugar and starch to yield heat to keep his body warm and give him muscular strength for his work or play.

What has been said of the ingredients of food may be briefly recapitulated as follows:

Ordinary food materials, such as meat, fish, eggs, potatoes, wheat, etc., consist of—

Refuse.—As the bones of meat and fish, shells of shellfish, skin of potatoes, bran of wheat, etc.

Edible portion.—As the flesh of meat and fish, the white and yolk of eggs, wheat flour, etc. The edible portion consists of *water* and *nutritive ingredients* or *nutrients.*

The principal kinds of nutritive ingredients are *protein*, *fats*, *carbohydrates*, and *mineral matters.*

The water, refuse, and salt of salted meat and fish are called nonnutrients. In comparing the values of different food materials for nourishment they are left out of account.

CLASSES OF NUTRIENTS.

The following are familiar examples of compounds of each of the four principal classes of nutrients:

PROTEIN.
- *Proteids.*
  - *Albuminoids*, e. g., albumen (white of eggs); casein (curd) of milk; myosin, the basis of muscle (lean meat); gluten of wheat, etc.
  - *Gelatinoids*, e. g., collagen of tendons; ossein of bones; which yield gelatin or glue, etc.
- Meats and fish contain very small quantities of so-called "extractives." They include kreatin and allied compounds, and are the chief ingredients of beef-tea and meat-extract. They contain nitrogen, and hence are commonly classed with protein.

Fats, e. g., fat of meat; fat (butter) of milk; olive oil; oil of corn, wheat, etc.

Carbohydrates, e. g., sugar, starch, cellulose (woody fiber), etc.

Mineral matters, e. g., phosphate of lime, sodium chloride (common salt), etc.

HOW FOOD IS USED IN THE BODY.

Blood and muscle, bone and tendon, brain and nerve—all the organs and tissues of the body—are built from the nutritive ingredients of food. With every motion of the body, and with the exercise of feeling and thought as well, material is consumed and must be resupplied by food. In a sense, the body is a machine. Like other machines it requires material to build up its several parts, to repair them as they are worn out, and to serve as fuel. In some ways it uses this material like a machine; in others it does not. The steam engine gets its power from fuel; the body does the same. In the one case coal or wood, in the other food, is the fuel. In both cases the energy which is latent in the fuel—the potential energy, as it is called in scientific language—is transformed into heat and power. When the coal is burned in the furnace a part of its potential energy is transformed into the mechanical power which the engine uses for its work; the rest is changed to heat which the engine does not utilize and which, therefore, is wasted. The potential energy of the food is transformed in the body into heat and mechanical power. The heat is used to keep the body warm. The mechanical power is employed for muscular work. The material of which the engine is built is very different from that which it uses for fuel, but part of the material which serves the body for fuel also builds it up and keeps it in repair. Furthermore, the body uses its own substance for fuel. This the steam engine can not do at all. The steam engine and the body are alike in that both convert the fuel into heat and mechanical power. They differ in that the body uses the same material for fuel as for building and also consumes its own material for fuel. In its use of fuel the body is much more economical than any engine.

The body is more than a machine. We have not simply organs to build and keep in repair and supply with energy; we have a nervous organization; we have sensibilities and the higher intellectual and spiritual faculties, and the right exercise of these depends upon the right nutrition of the body.

The chief uses of food, then, are two: (1) To form the material of the body and repair its wastes; (2) to yield heat to keep the body warm and muscular and other power for the work it has to do. In forming the tissues and the fluids of the body the food serves for building and repair. In yielding heat and power it serves as fuel.

The different nutrients of food serve the body in different ways. The principal tissue formers are the protein compounds, especially the albuminoids. These make the flesh of the body. They build up and repair the nitrogenous materials, as the muscles and tendons, and supply the albuminoids of the blood, milk, and other fluids. The chief fuel ingredients of the food are the carbohydrates and fats. These are either consumed in the body when the food is eaten or they are stored as fat to be used as occasion demands.

The albumen of eggs, the casein of milk and cheese, the gluten of wheat, the myosin of lean meat, and the other albuminoids of food are transformed into the albuminoids and gelatinoids of the body. Muscle, tendon, and cartilage are made of albuminoids.

The albuminoids of food also serve as fuel. A dog can live on lean meat; he can convert it into muscle, heat, and muscular power. The gelatinoids of food, as the finer particles of tendon and the gelatin, which is dissolved out of bone and meat in making soup, though somewhat similar to the albuminoids in composition, are not tissue formers. But they are used as fuel and hence are valuable nutrients.

The albuminoids are sometimes called "flesh formers" or "muscle formers" because the lean flesh, the muscle, is made from them.

The starch of bread and potatoes, and sugar, are burned in the body to yield heat and power. The fats, such as the fat of meat and butter, serve the same purpose, only they are a more concentrated fuel than the carbohydrates.

The fats of the food are stored in the body. The body also transforms the carbohydrates of food into fat. This fat, and with it that stored from the fat of food, is kept in the body as a reserve of fuel in the most concentrated form. One chief use of the fat stored in the body is for fuel, to be drawn on in case of need.

The different nutrients can to a greater or less extent do one another's work. If the body has not enough of one for fuel it can use another. But while the protein can be burned in the place of fats and carbohydrates, neither of the latter can take the place of the albuminoids in building and repairing the tissues. At the same time the gelatinoids, fats, and carbohydrates, by being consumed themselves, protect the albuminoids from consumption.

THE FUEL VALUE OF FOOD.

Heat and muscular power are forms of force or energy. The energy is developed as the food is consumed in the body. It is measured in the laboratory by means of an apparatus called the calorimeter. The unit commonly used is the calorie, the amount of heat which would raise the temperature of a pound of water four degrees Fahrenheit.

Taking ordinary food materials as they come, the following general estimate has been made for the average amount of heat and energy in 1 pound of each of the classes of nutrients:

	Calories.
In 1 pound of protein	1, 860
In 1 pound of fats	4, 220
In 1 pound of carbohydrates	1, 860

In other words, when we compare the nutrients in respect to their fuel values, their capacities for yielding heat and mechanical power, a pound of protein of lean meat or albumen of egg is just about equivalent to a pound of sugar or starch, and a little over 2 pounds of either would be required to equal a pound of the fat of meat or butter or the body fat.

Before the invention of matches, blacksmiths used to start their fires with iron heated by hammering. The heating of the iron was a case of the conversion of one form of energy into another. The muscular energy of the blacksmith's arm was transformed into the mechanical energy of the descending hammer; when the hammer struck, the energy was imparted to the iron, where it was transmuted into heat, and the iron became red-hot. The energy came from the blacksmith's food. Just how all the energy of the food is disposed of in the body, experimental science has not yet told us. But it is certain that part of it is converted into heat and part into the mechanical energy exerted by the muscles. Some of it may be transformed into electricity.

There is no doubt that intellectual activity, also, is somehow dependent upon the consumption of material which the brain has obtained from the food, but just what substances are consumed to produce brain and nerve force, and how much of each is required for a given quantity of intellectual labor, are questions which the chemist's balance and calorimeter do not answer.

The coal and wood we burn, the plants we grow, the food we eat, and the reserve materials in our bodies are reservoirs of latent energy. The source of that energy is the sun. The science of later years is explaining how the energy of the sun warms and lights our planet; how it is stored in coal and petroleum and wood; and how it is transformed into the heat of the furnace, the light of the lamp, the mechanical power of steam, or into electricity and then into light or heat or mechanical power again. The same energy from the sun is stored in the protein and fats and carbohydrates of food, and the physiologists to-day are telling us how it is transmuted into the heat that warms our bodies and into strength for our work and thought.

What has been said above about the ways in which our food nourishes us may be briefly summarized as follows:

WAYS IN WHICH FOOD IS USED IN THE BODY.

Food supplies the wants of the body in several ways. It either—

- Is used to form the tissues and fluids of the body;
- Is used to repair the wastes of tissues;
- Is stored in the body for future consumption;
- Is consumed as fuel, its potential energy being transformed into heat or muscular energy, or other forms of energy required by the body; or,
- In being consumed protects tissues or other food from consumption.

USES OF THE DIFFERENT CLASSES OF NUTRIENTS.

Protein forms tissue (muscle, tendon, etc., and fat) and serves as fuel. Fats form fatty tissue (not muscle, etc.) and serve as fuel. Carbohydrates are transformed into fat and serve as fuel.	All yield energy in form of heat and muscular strength.

In being themselves burned to yield energy the nutrients protect each other from being consumed. The protein and fats of body tissue are used like those of food. An important use of the carbohydrates and fats is to protect protein (muscle, etc.) from consumption.

DEFINITION OF FOOD AND FOOD ECONOMY.

The views thus presented lead to the following definitions: (1) Food is that which, taken into the body, builds tissues or yields energy; (2) the most healthful food is that which is best fitted to the wants of the user; (3) the cheapest food is that which furnishes the largest amount of nutriment at the least cost; (4) the best food is that which is both most healthful and cheapest.

We have, then, to consider the kinds and amounts of nutrients in different food materials, their digestibility, and the kinds and amounts needed for nourishment by people doing different kinds of work.

NUTRITIVE VALUES OF DIFFERENT FOOD MATERIALS.

The nutritive value of foods depends mainly upon the amounts and proportions of actually nutritive materials which they contain. Of course the digestibility and the ways in which they "agree and disagree" with different people are important factors of the nutritive value. We will consider first the chemical composition.

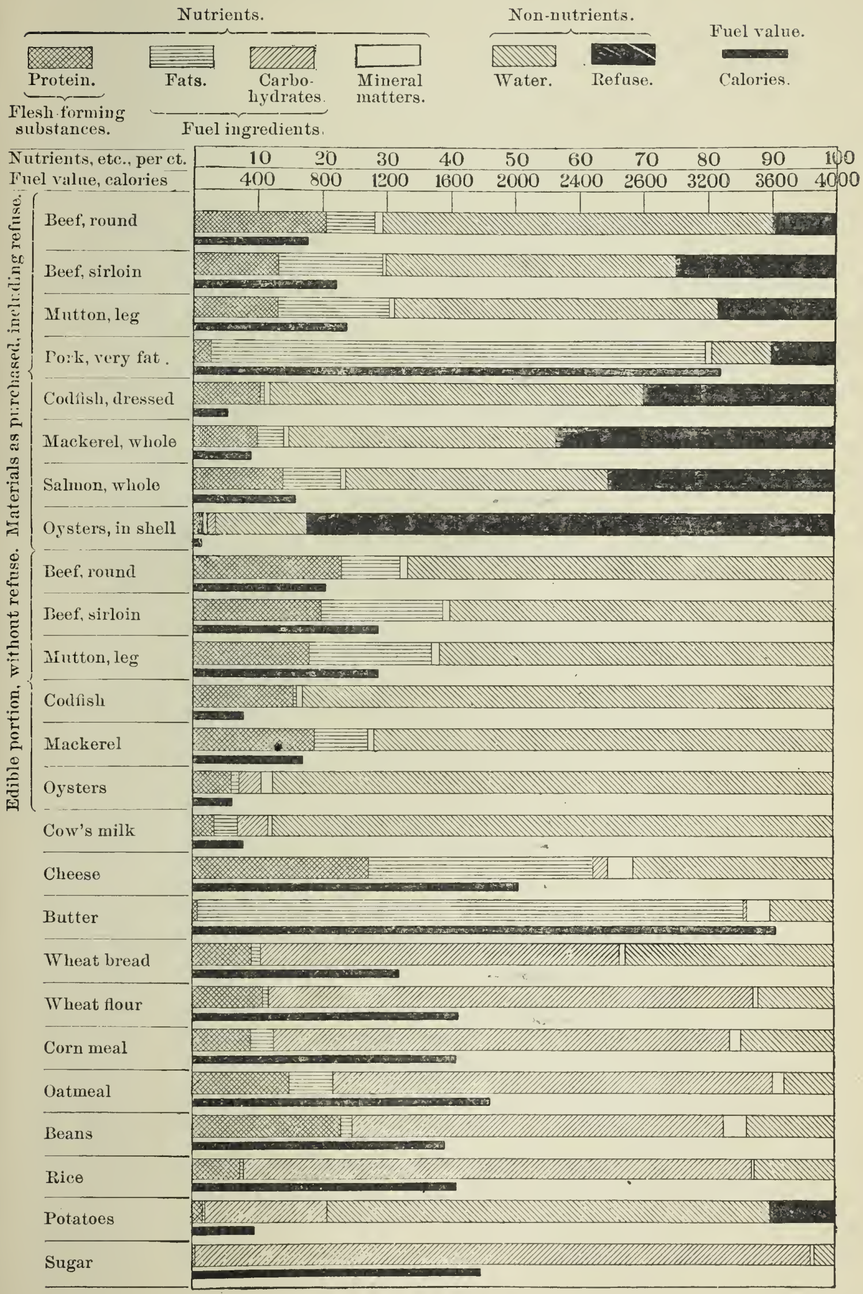
COMPOSITION OF FOOD MATERIALS.

Table A, page 26, gives the percentages of nutrients and the calories of energy found by analysis of specimens of different food materials. Chart 1, page 11, shows the composition of a smaller number, the nutrients, water, and refuse being indicated by bands, and the energy by black lines.

In considering the table and chart it must be remembered that many of our food materials as they are bought in the market include, along with the edible portion, more or less of what is called refuse, like the bone of meat, the shells of eggs, and skin of potatoes. The table and chart show the composition of these materials as we buy them and also the composition of the edible portion. Materials like milk, flour, and bread have no refuse.

CHART 1.—COMPOSITION OF FOOD MATERIALS.

Nutritive ingredients, refuse, and fuel value.



Another important consideration is the amount of water in the edible portion of the food, as also may be seen in Table A. In general, animal foods contain the most water and vegetable foods the most nutrients, though potatoes and turnips are exceptions, the former being three-fourths and the latter nine-tenths water. Butter, on the other hand, though one of the animal foods, generally has ten or more per cent of water. The milk from which it is made is not far from seven-eighths water. Meats have more water in proportion as they have less fats, and *vice versa*, the fatter the meat the less the amount of water in it. Thus, very lean beef (the muscle of a lean animal from which the fat has been trimmed off) may have 78 per cent of water and only 22 per cent of nutrients. The rather fat sirloin may have two-fifths, and very fat pork one-tenth or less of water. The flesh of fish is in general more watery than ordinary meats, that of salmon being five-eighths water, codfish over four-fifths, and flounder over six-sevenths. Flour and meal have but little water, and sugar when well dried has almost none.

In examining the proportions of individual nutrients, protein, fats, and carbohydrates, the most striking fact is the difference between the meats and fish on the one hand and the vegetable foods on the other. The vegetable foods are rich in carbohydrates, like starch and sugar, while the meats have not enough to be worth mentioning. On the other hand, the meats abound in protein and fats, of which the vegetable foods usually have but little. Beans and oatmeal, however, are rich in protein, while fat pork has very little.

In the first glance at a table like this people sometimes obtain a wrong impression. For instance, rice consists of about seven-eighths and potatoes only one-fourth nutritive materials. The first inference is that rice is more than three times as nutritious as potatoes. In one sense this is true; that is to say, a pound of rice contains more than three times as much nutrients as a pound of potatoes. But if we take enough of potatoes to furnish as much nutritive material as the pound of rice, the composition and nutritive value of the two will be just about the same. In cooking the rice we mix water with it, and may thus make a material not very different in composition from potatoes. By drying the potatoes they could be made very similar in composition and food value to rice. Taken as we find them, a pound of rice and 3½ pounds of potatoes would contain nearly equal weights of each class of nutrients and would have about the same nutritive value.

The fats have, weight for weight, about two and one-fourth times the potential energy of either the protein or the carbohydrates. Water has no potential energy. Hence the food materials which have the most fat and the least water have the highest fuel value. Butter and fat pork consist almost exclusively of fat. They lead the other food materials in fuel value. Lard, suet, and olive oil have even less water, and hence exceed the butter in this respect. Oleomargarine (see Table A) has about the same composition, fuel value and food value, as butter.

The different kinds of meat differ even more in proportions of fat than one would suppose from their appearance. The figures given in these tables represent the averages of analyses thus far made of American meats. Comparatively few samples have been analyzed, however, and probably future investigations will change these figures more or less. Indeed meats are so variable in composition that it is very difficult to say just what are the average figures. Generally speaking, veal is the leanest and pork the fattest of ordinary meats. Mutton is apt to be a little fatter than beef. Of the different cuts of beef the loin, rump, and shoulder are among the leanest, while the ribs and flank are the fattest. Mutton and lamb furnish about the same amount of protein and have the same fuel value as the fatter cuts of beef. The loin is the fatter part of beef and mutton. This is especially the case with mutton, because the leaf fat is usually included with the loin as it is sold in the markets, while in the case of beef the tallow and suet, and in the case of swine the leaf lard, are cut out. Pork is so much fatter than the flesh of beef and mutton that even the strictly "lean cuts," as the lean after the removal of the leaf is called, contain relatively as much fat as the fattest cuts of other meats. The case is similar with smoked ham, though the large proportion of fat is due in part to the loss of water in preparation. Among the prepared meats, canned corn beef, which is ordinarily cooked before canning, is worthy of especial notice. It has a large amount of both protein and fats. Like most other kinds of canned meats, the corned beef is free from bone. It furnishes more protein, pound per pound, than most kinds of fresh beef, and stands very high in fuel value.

Chicken and turkey have less fat than the fatter meats. In spite of their large amount of refuse, bone, etc., they furnish quite large quantities of protein.

Fish have in general so much refuse and the flesh contains so much water that the proportions of nutrients are smaller than in ordinary meats. The white-fleshed fish, as cod and haddock, have very little fat. Fish with darker meats, such as shad and mackerel, are rich in fats. Salmon has considerable fat and approaches beef in composition. The difference in composition between dry salt cod and fresh cod is due chiefly to the loss of water in the drying and salting. Many persons are surprised to learn that oysters have about the same proportions of nutrients as milk. Indeed, there is very little difference in the nutritive values of the two when estimated by the quantities of nutrients and energy. Milk is, however, more nearly a "perfect" or "normal" food, if it is right to call any single food perfect or normal. Oysters are so richly prized because of their flavor. Cheese made of whole milk contains nearly all of the nutrients of the milk except the milk sugar, and hence comes very nearly being a concentrated form of milk. Cheese made of skim milk has less fat, and hence relatively more protein.

Among the vegetable foods the chief differences to notice are the proportions of water and of protein. The quantities of water range from

90 per cent or more in beets and turnips to as low as 10 per cent in some kinds of flour. In general, dry seeds, like wheat, corn, and beans, and the different kinds of flour and meal prepared from them, contain not far from one-eighth water and seven-eighths nutrients. Beans and peas contain the largest proportions of protein, and corn meal, potatoes, rice, turnips, and beets the least. Among the cereals wheat is the richest in protein. Doubtless this is one chief reason why it is so largely used for food. Oatmeal has rather more protein than wheat flour.

The comparison of wheat bread with wheat flour is interesting. The chief difference in the composition of flour and bread is the proportion of water, which makes about one-eighth the weight of flour and one-third that of the bread. The average composition of wheat flour and the bakers' bread made from it is about as follows:

Comparison of flour and bread.

	Water.	Nutrients.					Fuel value of 1 pound.
		Total.	Protein.	Fats.	Carbohydrates.	Mineral matters.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
Wheat flour	12	88	12	1	74	1	1,640
Bakers' bread	32	68	9	2	56	1	1,300

In making the bread, a little butter or lard, salt, and yeast, and considerable water, either by itself or in milk, are added to the flour. The yeast causes carbohydrates (sugar, etc.) to ferment, yielding alcohol and carbonic acid in the form of gas, which makes the dough porous. In the baking, the alcohol is changed to vapor and the carbonic acid is expanded, making bread still more porous, and both are mostly driven off. Part of the water escapes with them. The amount of sugar and other carbohydrates lost by the fermentation is not very large, generally from 1½ to 2 per cent of the weight of the flour used. With increase in the proportion of water in the bread as compared with the flour the proportion of nutrients is diminished, but the addition of shortening and salts brings up the fat and minerals in the bread, so that the proportions are larger than in the flour. In practice 100 pounds of flour will make from 133 to 137 pounds of bread, an average being about 136 pounds.

Flour, such as is used by bakers, is now purchased in the Eastern States at not over $4 per barrel. This would make the cost of the flour in a pound of bread about 1½ cents. Allowing one-half cent for the shortening and salt, which is certainly very liberal, the materials for a pound of bread would cost not more than 2 cents. Of course there should be added to this the cost of labor, rent, interest on investment, expense of selling, etc., to make the actual cost to the baker.

Very few accurate weighings and analyses of bakers' bread have been made in this country, so far as I am aware, but the above statements represent the facts as nearly as I have been able to obtain them.

The average weight of a number of specimens of 10-cent loaves purchased in Middletown, Conn., was 1¼ pounds. This makes the price to the consumer 8 cents per pound. The price of bread and the size ot the loaf are practically the same now as when flour cost twice as much.

The cost of bakers' bread is a comparatively small matter to the person who only buys a loaf now and then, but in the Eastern States and in the larger towns throughout the country many people, and especially those with moderate incomes and the poor, buy their bread of the baker. Six cents a pound, or even half that amount, for the manufacture and distribution seems a very large amount.

In the large cities competition has made bread much cheaper, but even there the difference between the cost of bread to the well-to-do family who bake it themselves and to the family of the poor man who buys it of the baker is unfortunately large.

THE DIGESTIBILITY OF FOOD.

"We live not upon what we eat, but upon what we digest." In other words, the value of food for nutriment depends not only on how much of nutrients it contains, but also upon how much of these the body digests and uses for its support.

By digestibility of food several different things are, or may be, meant. Some of these, as the ease with which a given food material is digested, the time required for the process, the influence of different substances and conditions on digestion, and the effects upon health and comfort are so dependent upon the peculiarities of different individuals, and are so difficult of measurement as to make the laying down of hard-and-fast rules impossible. For our present purpose, the most important factor is the amount digested. This, fortunately, is more easy to determine. Understanding by the digestibility of a food the proportions of each of the nutrients which can be actually digested by healthy persons, the question can be answered more or less accurately by experiment.

Briefly expressed, the method consists in weighing and analyzing both the food consumed and the solid excrement. Since the latter represents the amount of food undigested and unassimilated, the difference is taken as the amount digested. A large number of such tests of the digestion of feeding stuffs by domestic animals have been made in European, and of late in American, experiment stations. The number of experiments upon the digestibility of food of man is small. Scarcely more than a hundred reliable series have been reported. The very large majority of them have been made in Germany, most of them with healthy men.

The results may be briefly summarized as follows:

(1) The protein of our ordinary meats, fish, and milk is very readily and completely digested. The protein of vegetable foods is much less completely digested than that of animal foods. Of that of potatoes, whole wheat, and rye flour one-fourth, or even one-third, may escape

digestion, and thus be useless for nourishment. Roughly speaking, one-sixth or one-seventh of the protein of wheat flour, corn meal, beans, and peas may be assumed to be undigested when cooked and eaten in the usual way.

(2) Much of the fats of animal food may at times fail of digestion. This is presumably true of vegetable fats, but the quantities are in general so small that the determinations of the proportions digested are not very accurate. The experiments thus far made imply that perhaps 5 per cent of the fat of meats, eggs, milk, butter, oleomargarine and lard will escape digestion as they are ordinarily eaten.

(3) The carbohydrates, which make up a large part of vegetable food, are in general very completely digestible. The crude fiber, or cellulose, is an exception, but the quantities of this in the materials used for the food of man are too small to be of importance. Sugar is believed to be completely digested. This is assumed to be the case with the sugar of milk. The other carbohydrates of animal foods are very small in amount.

(4) The animal foods have in general the advantage of the vegetable foods in digestibility in that they contain more protein and that their protein is more digestible.

(5) The quantity digested appears to be less affected by flavor, flavoring materials, and food adjuncts, and to differ less with different persons than is commonly supposed.

One important thing to remember is that the food we digest is not always utilized to the best advantage. Different people differ greatly in this respect. One man may be able to do a large amount of work and another very little when both have the same diet and digest the same amounts of nutrients from it. One person will grow fat upon an amount of digested material with which another will not gain in weight at all. The getting of the most good from food is not so much a matter of digestion as of making use of what is digested.

THE FITTING OF FOOD TO THE NEEDS OF THE BODY.

In the adjusting of diet to the demands of the body, the important matter is to provide enough protein for the building and repair of tissue and enough energy to keep it warm and do its work. Considering the body as a machine, there must be material to make it and keep it in repair and fuel to supply heat and power. If there is not food enough or the nutrients are not in the right proportions, the body will be weak in its structure and inefficient in its work. So, likewise, if there is too much, damage to health will result.

While this is true as a general principle, and while this principle is the fundamental one in food economy, there are many modifications in detail, not as many as there are different persons and different kinds of food to be fitted to their peculiarities of digestion and assimilation, but still very many.

Thus, people in poor health or with weak digestion or with certain peculiarities of the nutritive system, are often obliged to be very particular in the selection of their food. A man who can ordinarily "eat anything" may be forced, in illness, to live on gruel or beef tea. The numerous food preparations for people with weak digestion are made in response to an actual and pressing need of partially digested, or at least of easily digestible, nutriment. Of the meat extracts in the market some contain very little and others practically no material which builds tissue or yields energy. In other words they have little real nutriment and sometimes almost none. They are as much medicine as food, but often their value is inestimable.

There are people who, because of some peculiarity of the alimentary system, are debarred from using foods which for people in general are most wholesome and nutritious. Some persons can not endure eggs, others suffer if they take milk, others have to avoid certain kinds of meat, and others suffer nausea or severe pain if they eat fruits which are generally agreeable to the taste and healthful in their effect. But these are exceptions.

In such matters we are apt to be impressed by the exception rather than the rule. It is nevertheless true for a great majority of people—for nearly every one who is in good health and uses the ordinary standard, wholesome foods—that a healthful diet is that which supplies the quantities of nutrients which the body requires.

Of course there is a great difference in the requirements of different people. The kinds and amounts of food best fitted for nourishment vary not only with sex, age, size, occupation, and climate, but also with the peculiarities of the individual. But it is possible in a general way to estimate the amounts of actual nutrients needed on the average by people of different classes and occupations.

DIETARIES AND DIETARY STANDARDS.

As the outcome of a great deal of observation and experiment, nearly all in Europe, standards have been proposed for the amounts of nutrients and energy in the daily food required by different classes of people. Those of Prof. Voit, of Munich, Germany, are most commonly accepted by specialists in Europe. Voit's standard for a laboring man at moderately hard muscular work calls for about 0.25 pound of protein and quantities of carbohydrates and fats sufficient, with the protein, to yield 3,050 calories of energy. Taking into account the more active life in the United States, and the fact that well-nourished people of the working classes here eat more and do more work than in Europe and in the belief that ample nourishment is necessary for doing the most and the best work, I have ventured to suggest a standard with 0.28 pound of protein and 3,500 calories of energy for the man at moderate muscular work.

TABLE 1.—*American and European dietaries and dietary standards.*

[Quantities per man per day.]

Dietaries.	Nutrients.			Fuel value.	Nutritive ratio.*
	Protein.	Fats.	Carbohydrates.		
American (Massachusetts and Connecticut).	*Lbs.*	*Lbs.*	*Lbs.*	*Cal.*	*1:*
Family of carpenter in Middletown, Conn	.25	.28	.76	3,055	5.5
Family of glass-blowers in East Cambridge, Mass	0.23	0.29	1.06	3,590	8.2
Boarding house, Lowell. Mass.; boarders, operatives in cotton mills	.29	.44	1.21	4,650	7.6
Boarding house, Middletown, Conn.; well-paid machinists, etc., at moderate work: Food purchased	.28	.41	.94	4,010	6.8
Food eaten	.23	.34	.84	3,490	7.3
Blacksmiths, Lowell, at hard work	.44	.67	1.75	6,905	7.4
Brickmakers, Massachusetts; 237 persons at very severe work	.40	.81	2.54	8,850	11
Mechanics, etc., in Massachusetts and Connecticut; average of 4 dietaries of mechanics at severe work	.48	.65	1.65	6,705	6.6
Average of 20 dietaries of wage-workers in Massachusetts and Connecticut	.34	.50	1.38	5,275	7.5
Average of 5 dietaries of professional men and college students in Middletown, Conn: Food purchased	.30	.36	1.12	4,140	6.6
Food eaten	.27	.34	1.08	3,925	6.6
European (English, German, Danish, and Swedish).					
Well-fed tailors, England, Playfair	.29	.09	1.16	3,055	4.7
Hard-worked weavers, England, Playfair	.34	.09	1.37	3,570	4.8
Blacksmiths at active labor. England, Playfair	.39	.16	1.47	4,115	4.7
Mechanic, Munich, 60 years old, in comfortable circumstances, light work, Forster	.26	.15	.76	2,525	4.3
Well-paid mechanics, Munich, Voit	.34	.12	1.06	3,085	4
Carpenters, coopers, locksmiths, Bavaria; average of 11 dietaries, Voit	.27	.08	1.28	3,150	5.3
Miners at severe work, Prussia, Steinheil	.30	.25	1.40	4,195	6.7
Brickmakers (Italians), Munich, diet mainly maize meal and cheese, severe work, Ranke	.37	.26	1.49	4,540	5.6
German army ration, peace footing	.25	.09	1.06	2,800	5
German army ordinary ration, war footing	.30	.13	1.08	3,095	4.6
German army extraordinary ration, in war	.42	.10	1.49	3,985	4.1
University professor, Munich; very little exercise, Ranke.	.22	.22	.53	2,325	4.7
Lawyer, Munich, Forster	.18	.28	.49	2,400	6.3
Physician, Munich, Forster	.28	.20	.80	2,830	4.4
Physician, Copenhagen, Jurgensen	.30	.31	.53	2,835	4.1
Average of 7 dietaries of professional men and students, Germany, Denmark, and Sweden	.25	.22	.63	2,670	4.7
Dietary standards.					
Adult in full health, Playfair	.26	.11	1.17	3,140	5.5
Active laborers, Playfair	.34	.16	1.25	3,630	4.7
Man at moderate work, Moleschott	.29	.09	1.21	3,160	4.9
Man at moderate work, Voit	.26	.12	1.10	3,055	5.3
Man at hard work. Voit	.32	.22	.99	3,370	4.7
Man with little physical exercise, Atwater	.20	.20	.66	2,450	5.5
Man with light muscular work, Atwater	.22	.22	.77	2,800	5.7
Man with moderate muscular work, Atwater	.28	.28	.99	3,520	5.8
Man with active muscular work, Atwater	.33	.33	1.10	4,060	5.6
Man with hard muscular work, Atwater	.39	.55	1.43	5,700	6.9

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*The nutritive ratio is the ratio of the protein to the sum of all the other nutritive ingredients. The fuel value of the fat is two and a quarter times that of the protein and carbohydrates. In calculating the nutritive ratio the quantity of fats is multiplied by two and one-fourth. This product is added to the weight of the carbohydrates. The sum divided by the weight of the protein gives the nutritive ratio. Materials with large amounts of fats or carbohydrates and little protein, like fat meats or potatoes, have a "wide" nutritive ratio. Those with a large amount of protein as compared with the carbohydrates and fats, like lean meat, codfish, and beans, have a "narrow" nutritive ratio. In other words, the materials rich in tissue-forming substances have a narrow, and those with a large preponderance of fuel materials have a wide, nutritive ratio. This is an important matter in the adjusting of food to the demands of the body.

A well-balanced diet is one which has the right ratio of protein to the fats and carbohydrates. A relative excess of the tissue formers makes the ratio narrow, while an excess of the fuel ingredients makes an overwide ratio in the diet. Either of these errors is disadvantageous. Our food materials and our diet are apt to have too wide a nutritive ratio. In other words, we consume on the whole relatively too little protein and too much of the carbohydrates and fats.

Just what compounds in food are needed for the nutriment of the brain physiological chemistry has yet to tell us, but it is certain that people with little muscular exercise require less food than those who labor. Well-to-do professional men and students in Europe with less muscular exercise than mechanics have been found to be well nourished with an average of 0.23 pound of protein and 2,700 calories of energy. In the cases observed in the United States the amounts eaten by professional men have been much larger.

The figures of Table 1, which are taken from a large number reported by different investigators, will serve to show how the actual dietaries of people of different classes at home and abroad compare with the standard dietaries which have been proposed as the result of observations and experiments. The figures for European dietaries are mostly by Voit and his followers in Germany, and by Playfair in England; the American figures are by the writer and his associates; all are based upon the observations of actual dietaries.

The dietary standards of the same table are intended to represent the average needs as nearly as they can be estimated from the data now at hand. Much more inquiry will be necessary to make them as reliable as is to be desired.

CALCULATION OF DAILY DIETARIES.

On the basis of the standards for dietaries given on page 18, various combinations of food materials for daily dietaries may be made by calculations from Table A (p. 26). Thus if a dietary for a man at moderately hard muscular work is to be made up of round beefsteak, butter, potatoes, and bread, it may be calculated as follows:

		Protein.	Calories.			Protein.	Calories.
		Pounds.				*Pounds.*	
Round steak.	1 pound contains..	.18	855	Round steak	13 ounces contain.	.14	695
Butter	1 pound contains..	.01	3,615	Butter......	3 ounces contain..	....	680
Potatoes.....	1 pound contains..	.019	325	Potatoes....	6 ounces contain.	.02	320
Wheat bread.	1 pound contains..	.088	1,280	Wheat bread	22 ounces contain.	.12	1,760
					Total	.28	3,455
					Standard for man at moderate muscular work.	.28	3,500

A number of different dietaries calculated in this way are given on pages 29–31.

PECUNIARY ECONOMY OF FOOD.

The cost of food is the principal item of the living expenses of most people. The results of investigations into the cost of living of people with different incomes in Massachusetts, in Great Britain, and in Germany, made by the Massachusetts Bureau of Statistics some years ago, are summarized in the following table:

TABLE 2.—*Percentage of family income expended for subsistence.*

	Annual income.	Amount expended for food.	Per cent expended for food.
GERMANY.			
Workingmen	$225 to $300	$140 to $186	62
Intermediate class	450 to 600	248 to 330	55
In easy circumstances	750 to 1,100	375 to 550	50
GREAT BRITAIN.			
Workingmen	500	255	51
MASSACHUSETTS.			
Workingmen	350 to 400	224 to 256	64
Do	450 to 600	284 to 378	63
Do	600 to 750	360 to 450	60
Do	750 to 1,200	420 to 672	56
Do	Above 1,200	612	51

In parts of the West and South where food is very cheap its cost in proportion to other expenses is less, and sometimes falls a little below half the income.

The large majority of families in this country are said to have not over $500 a year to live upon. On the average more than half of this goes, and must go, for food. The cost of preparing food for the table, rent, clothing, and all other expenses must be provided from the remainder.

These statements apply less accurately to farmers than to the inhabitants of the larger towns, but, although the farmer produces much of his food, yet, taking everything into account, the expense for nutriment is large even for him.

Although the cost of food makes so large a part of the whole cost of living, and although the health and strength of all are so intimately connected with and dependent upon their diet, yet even the most intelligent people know less of the actual uses and values of their food for fulfilling its purposes than of almost any other of the necessities of life.

CHEAP VS. DEAR FOOD.

The cheapest food is that which supplies the most nutriment for the least money. The most economical food is that which is the cheapest and at the same time best adapted to the wants of the eater. The maxim that "the best is the cheapest" does not apply to food. The best food in the sense of that which is the finest in appearance and flavor and which is sold at the highest price is not generally the cheapest, nor is it always the most healthful or economical. Yet very many people seem to think that they must have this sort of food, and that to economize by using anything inferior in quality or cheaper in price would be a sacrifice of both dignity and principle.

Mr. Lee Meriwether, who has given much attention to this special subject, cites a case in point, that of a coal laborer who boasted: "No one can say that I do not give my family the best of flour, the finest of sugar, the very best quality of meat." He paid $156 a year for the nicest cuts of meat, which his wife had to cook before 6 in the morning or after half past 6 at night, because she worked all day in a factory. When excellent butter was selling at 25 cents a pound he paid 29 cents for an extra quality. He spent only $108 a year for clothing for his family of 9, and only $72 a year for rent in a close tenement house, where they slept in rooms without windows or closets. He indulged in this extravagance in food when much less expensive food materials, such as regularly come upon the tables of men of wealth, would have been just as nutritious, just as wholesome, and in every way just as good, save in its gratification to pride and palate. He was committing an immense economic blunder. Like thousands of others, he did so without understanding at all that it was a blunder.

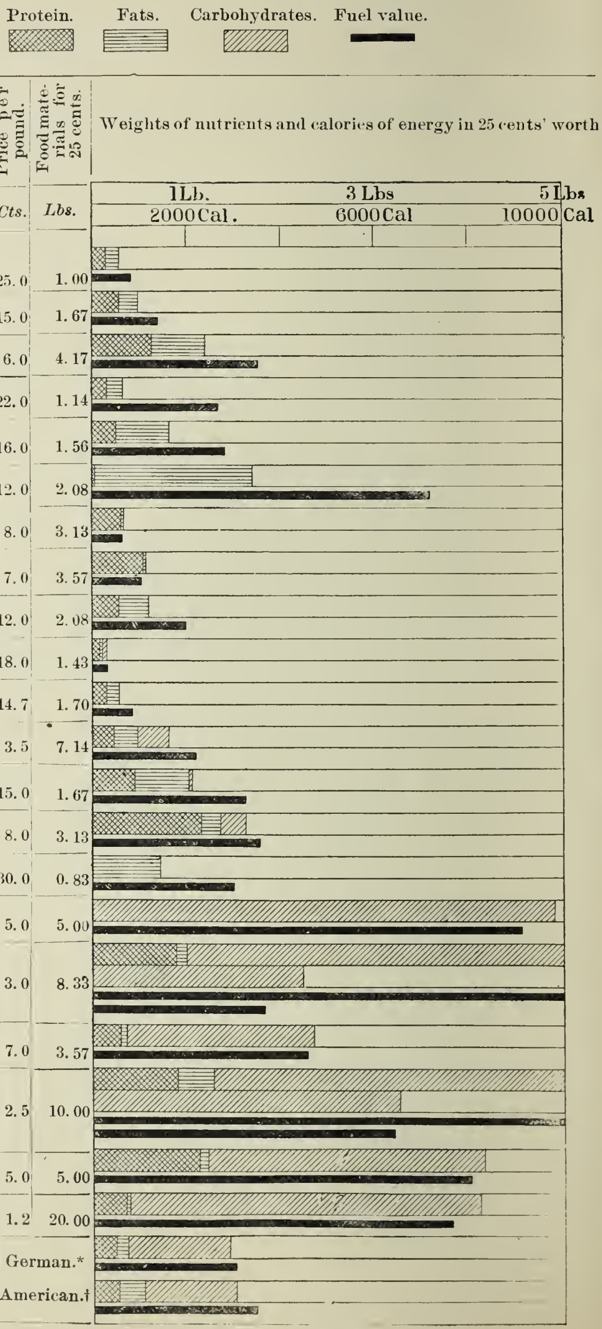
Just here is one great difficulty: the lack of information regarding the nutritive values of foods. Even those who wish and try to economize in their purchase and use of food do not understand how. They carefully consult the prices, but have in general very vague ideas about values for nourishment as compared with cost. Persons who are exceedingly economical in purchase of clothing and in other expenditures do not, and in many instances can not, practice intelligently the same economy at the markets. Frequently people pay from $1 to $2 a pound for the protein of the meat and other animal foods they use, when it might be obtained in forms equally wholesome and nutritious for 15 to 50 cents per pound. The food thus purchased is apt to supply some of the nutrients in excessive amounts as well as at needlessly high costs, while it furnishes others in insufficient quantities or in unfitting forms and in uneconomical ways, and only too often a large part of it finds its way into the drain or the garbage barrel instead of being utilized for nourishment. The difficulty is that in comparing different food materials with respect to their cheapness or dearness we are apt to judge them by the prices per pound, quart, or bushel, without much regard to the amounts or kinds of actual nutrients which they contain.

Of the different food materials which the market affords, and which are palatable, nutritious, and otherwise fit for nourishment, what ones are peculiarly the most economical? There are various ways of comparing food materials with respect to the relative cheapness or dearness of their nutritive ingredients. One, and perhaps the best, consists in comparing the nutrients obtained for a given sum in different materials. Estimates of the amounts of nutrients that could be purchased for 25 cents at the rates named are given in Table B (p. 28), and graphically shown in Chart 2 (p. 22). The calculations are based upon the analyses in Table A (p. 26).

CHART 2.—PECUNIARY ECONOMY OF FOOD.

Amounts of actually nutritive ingredients obtained in different food materials for 25 cents.

[Amounts of nutrients in pounds. Fuel value in calories.]



	Price per pound.	Food materials for 25 cents.
	Cts.	*Lbs.*
Beef, sirloin	25.0	1.00
Beef, round	15.0	1.67
Beef, neck	6.0	4.17
Mutton, leg	22.0	1.14
Ham, smoked	16.0	1.56
Salt pork, very fat	12.0	2.08
Codfish, fresh	8.0	3.13
Codfish, salt	7.0	3.57
Mackerel, salt	12.0	2.08
Oysters, 35 cents quart	18.0	1.43
Eggs, 25 cents dozen	14.7	1.70
Milk, 7 cents quart	3.5	7.14
Cheese, whole milk	15.0	1.67
Cheese, skim milk	8.0	3.13
Butter	30.0	0.83
Sugar	5.0	5.00
Wheat flour	3.0	8.33
Wheat bread	7.0	3.57
Corn meal	2.5	10.00
Beans	5.0	5.00
Potatoes	1.2	20.00
Standard for daily diet for man at moderate work	German.*	
	American.†	

* Voit. † Atwater.

The figures of Table B tell their story so plainly that they need very little comment. A quarter of a dollar invested in the sirloin of beef at 22 cents per pound pays for one and one-seventh pounds of the meat with three-eighths of a pound of actually nutritive material. This would contain one-sixth of a pound of protein and one-fifth of a pound of fat, and supply 1,120 calories of energy. The same amount of money paid for oysters at the rate of 50 cents per quart brings two ounces of actual nutrients, an ounce of protein, and 230 calories of energy. But in buying wheat flour at $7 a barrel, the 25 cents pay for six and a quarter pounds of nutrients, with eight-tenths of a pound of protein and 11,755 calories of energy.

The price of food is not regulated solely by its value for nutriment. Its agreeableness to the palate or to the buyer's fancy makes a large factor of the current demand and market price. There is no more nutriment in an ounce of protein or fat of the tenderloin of beef than in that of the round or shoulder. The protein of animal food does, however, have an advantage over that of vegetable foods. Animal foods, such as meats, fish, milk, and the like, gratify the palate in ways which most vegetable foods do not, and, what is perhaps of still greater weight in regulating the actual usage of communities by whose demand the prices are regulated, they satisfy a real need by supplying protein and fats, which vegetable foods lack.

People who can afford it, the world over, will have animal foods, and will compete with one another in the prices they give for them. In general, the animal foods are more easily and completely digested than vegetable. There is doubtless good ground for paying somewhat more for the same quantity of nutritive material in the animal food.

For persons in good health the foods in which the nutrients are most expensive are like costly articles of adornment. People who can well afford them may be justified in buying them, but they are not economical.

WASTE OF FOOD.

We waste food in two ways. We throw away a great deal, and many of us eat more than we need. That which is thrown away in the form of kitchen and table refuse does no harm, and in so far as it is used for feeding animals, or, in the case of fat, for making soap, it is not an absolute loss. That which we consume in excess of our needs is worse than wasted, because of the harm it does to the health.

In connection with studies of dietaries by the author and associates in New England, some observations have been made which bear upon this prevalent habit of throwing away valuable food. Thus, in the dietary of a carpenter 7.6 per cent of the total food purchased was left in the kitchen and table wastes. The total waste was somewhat worse than this proportion would imply, because it consisted mostly of the protein and fats, which are more costly than the carbohydrates. The waste contained about one-tenth of the total protein and fat, and only one twenty-fifth of the total carbohydrates of the food; or, to put it in another way, the food purchased contained nearly 10 per cent more protein, 12 per cent more fat, and 5 per cent more carbohydrates than were eaten; and, worst of all, the wasted protein and fats were mostly from the meats, which supplied them in the costliest form.

From the statistics of the amounts and composition of the table and kitchen wastes of a boarding house at Middletown, Conn., it appears that these contained one-ninth of the whole nutritive material of the food purchased. They included one-fifth of the protein and fats and one-twentieth of the carbohydrates. Here again the rejected portions were mostly from the meats. Except in so far as parts of the waste were fed to chickens or possibly used for soap, it was simply thrown away. The boarding house was a very good one, the mistress was counted an excellent housekeeper, and the boarders were mechanics and other thrifty and industrious people with only moderate incomes.

In the studies of dietaries of students' clubs in Middletown it was necessary to determine the weight and composition of the rejected portion of meats. In buying meat in the retail markets in this region it is a common practice to have the bone and considerable of the fat cut out and left. In thus removing the "trimmings" the butcher is apt to cut out considerable else than the bone and fat. In a piece of roast beef weighing 16 pounds, the "trimmings," which consisted of the bone and meat cut out with it, and which were left for the butcher to sell to the soap man or get rid of as he might otherwise choose, weighed 4½ pounds, so that 11½ pounds of meat went to the consumer, who, of course, paid for the whole. The butcher said that he sold this sort of beef largely to the ordinary people of the city—mechanics, small tradesmen, and laborers; that many of his customers preferred not to take the "trimmings;" and that they were not exceptionally large in this case, either in amount or in proportion of meat and bone, for that cut of beef, which was the "rib roast." Inquiries of other meat men brought similar information.

The 4½ pounds of "trimmings" consisted of, approximately, 2¼ pounds of bone and ½ pound of tendon ("gristle"), which would make a most palatable and nutritious soup, and 1¾ pounds of meat, of which 1 pound was lean and ¾ pound fat. It is estimated that the nutritive materials of meat thus left unused, saying nothing of the bone and tendon, contained some 15 per cent of the protein and 10 per cent of the potential energy of the whole. The price of the beef was $2.24. Assuming the nutritive value of the ingredients of the "trimmings" to be 12½ per cent of the whole, 28 cents worth of the nutritive material, besides the bone and tendon, was left at the butcher's.

The common saying that "the average American family wastes as much food as a French family would live upon" is a great exaggeration, but statistics show that there is a great deal of truth in it. Even in some of the most economical families the amount of food wasted, if it could be collected for a month or a year, would prove to be very large, and in many cases the amount would be little less than enormous.

We endeavor to make our diet suit our palate by paying high prices in the market rather than by skillful cooking and tasteful serving at home. We buy more than we need, and what makes the matter worse, it is frequently those who most need to save that are the most wasteful.

The remedy for the evil so far as it applies to the chief item of our living expenses, our food, must be sought in two ways—in an understanding of the elementary facts regarding food and nutrition, and the acceptance of the doctrine that economy is not only respectable, but honorable.

FOOD AND HEALTH.

The studies of dietaries thus far made are not sufficient for entirely reliable inferences regarding the eating habits of the people at large. The total number of dietaries examined is only a little over one hundred. They have been confined mostly to New England; only a small number of the examinations have been made with the needed accuracy; and it is worth noting that the ones in which the amounts and composition of the food have been most accurately determined are for the most part the ones in which the quantities were smallest, although some of the largest of the figures obtained were thought to represent very nearly the actual quantities.

Taking the results as they are, they very decidedly confirm the general impression of hygienists that our diet is one sided and that we eat too much. The food which we actually eat, leaving out of account that which we throw away, has relatively too little protein and too much fat, starch, and sugar. This is due partly to our large consumption of sugar and partly to our use of such large quantities of fat meats. The quantities of fat in the European dietaries, cited on page 18, range from 1 to 5 ounces per day, while in the American the range is from 4 to 16 ounces. In the daily food of well-to-do professional men in Germany, amply nourished, the quantity of fat is from 3 to 4½ ounces per day; while in the dietaries of Americans in similar conditions of life it ranges from 5 to 7½ ounces in the food purchased. The quantities of carbohydrates in the European dietaries range from 9 to 24 ounces, while in the corresponding American dietaries the carbohydrates were from 24 to 60 ounces.

In the American dietaries the ratio of fuel ingredients to one part of protein ranges from 6.6 to 8.2, and even higher. In the European dietaries of well-nourished people and in the dietary standards which express the average needs according to the teachings of the best physiological observations, it is from 4.1 to 6, or thereabouts. The rejection of so much of the fat of meat at the market and on our plates at the table is not mere willfulness. It is in obedience to nature's protest against a one-sided and excessive diet.

How much harm is done to health by our one-sided and excessive diet no one can say. Physicians tell us that it is very great. Of the vice of overeating, as practiced by the well-to-do classes, in England especially, Sir Henry Thompson, a noted English physician and authority on this subject, says:

"I have come to the conclusion that more than half the disease which embitters the middle and latter part of life is due to avoidable errors in diet, * * * and that more mischief in the form of actual disease, of impaired vigor, and of shortened life accrues to civilized man * * * in England and throughout central Europe from erroneous habits of eating than from the habitual use of alcoholic drink, considerable as I know that evil to be."

APPENDIX.

Table A gives the proportions of ingredients in a number of food materials as found by analysis of specimens collected for the most part in New York and New England markets. They will doubtless be modified by the results of future and more numerous analyses.

The figures of Table B are obtained from Table A, as stated on page 21. The range of prices of the same materials is little if any wider than actually exists at present.

The calculations of Table D are made as explained on page 19. It will be observed that they conform to the dietary standard on page 28, for a "man at moderately hard muscular work."

Table A.—*Composition of different food materials.*

Food materials.	Refuse (bones, skin, shell, etc.).	Edible portion.						
		Water.	Nutrients.					Fuel value of 1 pound.
			Total.	Protein.	Fat.	Carbohydrates.	Mineral matters.	
Animal foods, as purchased.								
Beef:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cal.*
Neck	20	49.6	30.4	15.6	14	....	.8	880
Shoulder	12.6	55.8	31.6	17	13.7	....	.9	895
Chuck rib	14.6	49.5	35.9	15	20.1	....	.8	1,125
Rib	21	38.2	40.8	12.2	27.9	....	.7	1,405
Sirloin	19.5	48.3	32.2	15	16.4	....	.8	970
Round steak	7.8	60.9	31.3	18	12.3	....	1	855
Side, without kidney fat	19.2	44.3	36.5	13.9	21.8	....	.8	1,180
Rump, corned	5	70.8	24.2	16.7	5.1	....	2.4	525
Flank, corned	12.1	43.7	44.2	12.4	29.2	....	2.6	1,460
Veal, shoulder	17.9	56.7	25.4	16.6	7.9	....	.9	640
Mutton:								
Shoulder	16.3	49	34.7	15.1	18.8	....	.8	1,075
Leg	18.1	50.6	31.3	15	15.6	....	.7	935
Loin	15.8	41.5	42.7	12.6	29.5	....	.6	1,480
Side, without kidney fat	17.3	44.2	38.5	14	23.7	....	.8	1,260
Pork:								
Shoulder roast, fresh	14.6	43	42.4	13.6	28	....	.8	1,435
Ham, salted, smoked	11.4	36.8	51.8	14.8	34.6	....	2.4	1,735
Chicken	38.2	44.6	17.2	15.1	1.2	....	.9	330
Turkey	32.4	44.7	22.9	16.1	5.9	....	.9	550
Eggs, in shell	13.7	63.1	23.2	12.1	10.2	....	.9	655
Fish, etc.:								
Flounder, whole	66.8	27.2	6	5.2	.3	....	.5	110
Bluefish, dressed	48.6	43	11.1	9.8	.6	....	.7	210
Codfish, dressed	29.9	58.5	11.6	10.6	.2	....	.8	205
Shad, whole	50.1	35.2	14.7	9.2	4.8	....	.7	375
Mackerel, whole	44.8	40.4	15	10	4.3	....	.7	365
Halibut, dressed	17.7	61.9	20.4	15.1	4.4	....	.9	465
Salmon, whole	35.3	40.6	24.1	14.3	8.8	....	1	635
Salt codfish	42.1	40.5	17.6	16	.4	....	1.2	315
Smoked herring	50.9	19.2	29.9	20.2	8.8	....	.9	745
Salt mackerel	40.4	28.1	31.5	14.7	15.1	....	1.7	910
Canned salmon	4.9	59.3	35.8	19.3	15.3	....	1.2	1,005
Lobsters	62.1	31	6.9	5.5	.7	.1	.6	135
Oysters	82.3	15.4	2.3	1.1	.2	.6	.4	40

TABLE A.—*Composition of different food materials*—Continued.

Food materials.	Refuse (bones, skin, shell, etc.).	Edible portion.						
		Water.	Nutrients.					Fuel value of 1 pound.
			Total.	Protein.	Fat.	Carbohydrates.	Mineral matters.	
Animal foods, edible portion.								
Beef:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Cal.*
Neck		62	38	19.5	17.5		1	1,100
Shoulder		63.9	36.1	19.5	15.6		1	1,020
Chuck rib		58	42	17.6	23.5		.9	1,320
Rib		48.1	51.9	15.4	35.6		.9	1,790
Sirloin		60	40	18.5	20.5		1	1,210
Round		68.2	31.8	20.5	10.1		1.2	805
Side, without kidney fat		54.8	45.2	17.2	27.1		.9	1,465
Rump, corned		58.1	41.9	13.3	26.6		2	1,370
Flank, corned		49.8	50.2	14.2	33		3	1,655
Veal, shoulder		68.8	31.2	20.2	9.8		1.2	790
Mutton:								
Shoulder		58.6	41.4	18.1	22.4		.9	1,280
Leg		61.8	38.2	18.3	19		.9	1,140
Loin		49.3	50.7	15	35		.7	1,755
Side, without kidney fat		53.5	46.5	16.9	28.7		.9	1,525
Pork:								
Shoulder roast, fresh		50.3	49.7	16	32.8		.9	1,680
Ham, salted, smoked		41.5	58.5	16.7	39.1		2.7	1,960
Fat, salted		12.1	87.9	.9	82.8		4.2	3,510
Sausage:								
Pork		41.5	58.8	13.8	42.8		2.2	2,065
Bologna		62.4	37.6	18.8	15.8		3	1,015
Chicken		72.2	27.8	24.4	2		1.4	540
Turkey		66.2	33.8	23.9	8.7		1.2	810
Eggs		73.8	26.2	14.9	10.5		.8	721
Milk		87	13	3.6	4	4.7	7	325
Butter		10.5	89	1	85	.5	3	3,615
Oleomargarine		11	89.5	.6	85	.4	3	3,605
Cheese:								
Full cream		30.2	69.8	28.3	35.5	1.8	4.2	2,070
Skim milk		41.3	58.7	38.4	6.8	8.9	4.6	1,165
Fish:								
Flounder		84.2	15.8	13.8	.7		1.3	285
Haddock		81.7	18.3	16.8	.3		1.2	325
Codfish		82.6	17.4	15.8	.4		1.2	310
Shad		70.6	29.4	18.6	9.5		1.3	745
Mackerel		73.4	26.6	18.2	7.1		1.3	640
Halibut		75.4	24.6	18.3	5.2		1.1	560
Salmon		63.6	36.4	21.6	13.4		1.4	965
Salt cod		53.6		21.4	.3		1.6	410
Herring, salt		34.6		36.4	15.8		1.5	1,345
Mackerel, salt		43.4		17.3	26.4		2.6	1,860
Oysters		87.1	12.9	6	1.2	3.7	2	230
Vegetable foods.								
Wheat flour		12.5	87.5	11	1.1	74.9	.5	1,645
Graham flour (wheat)		13.1	86.9	11.7	1.7	71.7	1.8	1,625
Rye flour		13.1	86.9	6.7	.8	78.7	.7	1,625
Buckwheat flour		14.6	85.4	6.9	1.4	76.1	1	1,605
Oatmeal		7.6	92.4	15.1	7.1	68.2	2	1,850
Corn meal		15	85	9.2	3.8	70.6	1.4	1,645
Rice		12.4	87.6	7.4	.4	79.4	.4	1,630
Peas		12.3	87.7	26.7	1.7	56.4	2.9	1,565
Beans		12.6	87.4	23.1	2	59.2	3.1	1,615
Potatoes		78.9	21.1	2.1	.1	17.9	1	375
Sweet potatoes		71.1	28.9	1.5	.4	26	1	530
Turnips		89.4	10.6	1.2	.2	8.2	1	185
Carrots		88.6	11.4	1.1	.4	8.9	1	200
Onions		87.6	12.4	1.4	.3	10.1	.6	225
String beans		87.2	12.8	2.2	.4	9.4	.8	235
Green peas		78.1	21.9	4.4	.6	16	.9	405
Green corn		81.3	18.7	2.8	1.1	13.2	.6	345
Tomatoes		96	4	.8	.4	2.5	.3	80
Cabbage		91.9	8.1	2.1	.3	5.5	1.1	155
Apples		83.2	16.8	.2	.4	15.9	.3	315
Sugar, granulated		2	98			97.8	.2	1,820
Molasses		24.6	75.4			73.1	2.3	1,360
White bread (wheat)		32.3	67.7	8.8	1.7	56.3	.9	1,280
Boston crackers		8.3	91.7	10.7	9.9	68.7	2.4	1,895

TABLE B.—*Amounts of nutrients furnished for 25 cents in food materials at ordinary prices.*

Food materials as purchased.	Prices per pound.	Twenty-five cents will pay for—					
		Total food materials.	Nutrients.				Fuel value.
			Total.	Protein.	Fats.	Carbohydrates.	
	Cents.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Calories.*
Beef, sirloin	10	2.50	.79	.38	.41	....	2,425
Do	15	1.67	.52	.25	.27	....	1,620
Do	20	1.25	.39	.19	.20	....	1,215
Do	25	1	.31	.15	.16	....	970
Beef, round	8	3.13	.95	.56	.39	....	2,675
Do	12	2.08	.63	.37	.26	....	1,780
Do	16	1.56	.47	.28	.19	....	1,335
Beef, neck	4	6.25	1.85	.98	.87	....	5,500
Do	6	4.17	1.23	.65	.58	....	3,670
Do	8	3.13	.93	.49	.44	....	2,755
Mutton, leg	8	3.13	.96	.47	.49	....	2.925
Do	14	1.79	.55	.27	.28	....	1,675
Do	20	1.25	.38	.19	.19	....	1,170
Ham, smoked	10	2.50	1.23	.37	.86	....	4,340
Do	16	1.56	.77	.23	.54	....	2,705
Salt pork	10	2.50	2.09	.02	2.07	....	8,775
Do	14	1.79	1.50	.02	1.48	....	6,285
Do	18	1.39	1.16	.01	1.15	....	4,880
Codfish, fresh	6	4.17	.45	.44	.01	....	855
Do	10	2.50	.27	.27	....	....	510
Codfish, dried salt	6	4.17	.68	.67	.01	....	1,315
Do	8	3.13	.51	.50	.01	....	985
Mackerel, salt	10	2.50	.74	.37	.37	....	2,275
Do	15	1.67	.49	.24	.25	....	1,520
Oysters, 25 cents per quart	12.5	2	.24	.13	.03	.08	520
Oysters, 35 cents per quart	17.5	1.43	.17	.09	.02	.06	370
Oysters, 50 cents per quart	25	1	.12	.06	.02	.04	260
Eggs, 15 cents per dozen	8.8	2.84	.63	.34	.29	....	1,860
Eggs, 25 cents per dozen	14.7	1.70	.38	.21	.17	....	1,115
Eggs, 35 cents per dozen	20.6	1.21	.27	.15	.12	....	790
Milk, 3 cents per quart	1.5	16.67	2.05	.60	.67	.78	5,420
Milk, 6 cents per quart	3	8.33	1.02	.30	.23	.39	2,705
Milk, 8 cents per quart	4	6.25	.77	.23	.25	.29	2,030
Cheese, whole milk	12	2.08	1.36	.59	.74	.03	4,305
Do	15	1.67	1.09	.47	.59	.03	3,455
Do	18	1.39	.91	.39	.49	.03	2,875
Cheese, skim milk	6	4.17	2.25	1.60	.28	.37	4,860
Do	8	3.13	1.69	1.20	.21	.28	3,645
Do	10	2.50	1.35	.96	.17	.22	2,910
Butter	15	1.67	1.45	.02	1.42	.01	6,035
Do	25	1	.86	.01	.85	....	3.615
Do	35	.71	.61	.01	.60	....	2.565
Sugar	5	5	4.89	....	....	4.89	9,100
Do	7	3.57	3.50	....	....	3.50	6.495
Wheat flour	2	12.50	10.87	1.37	.14	9.36	20,565
Do	2.5	10	8.70	1.10	.11	7.49	16,450
Do	3	8.33	7.24	.91	.09	6.24	13,705
Wheat bread	3	8.33	5.56	.73	.14	4.69	10,660
Do	5	5	3.34	.44	.08	2.82	6,400
Do	8	3.13	2.09	.28	.05	1.76	4,005
Corn meal	2	12.50	10.45	1.15	.47	8.83	20,565
Do	3	8.33	6.97	.77	.32	5.88	13,705
Oatmeal	3	8.23	7.51	1.22	.59	5.70	15,370
Do	5	5	4.52	.74	.36	3.42	9,225
Rice	6	4.17	3.64	.31	.02	3.31	6,795
Do	8	3.13	2.73	.23	.01	2.49	5,100
Beans	5	5	4.22	1.16	.10	2.96	8,075
Potatoes, 45 cents per bushel	0.75	33.33	5.70	.60	.03	5.07	10,665
Potatoes, 60 cents per bushel	1	25	4.27	.45	.02	3.80	8,000
Potatoes, 90 cents per bushel	1.5	16.67	2.85	.30	.02	2.53	5,335

DIETARY STANDARDS.

	Nutrients.				Fuel value.
	Total.	Protein.	Fats.	Carbohydrates.	
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Calories.*
Man with light exercise	1.32	.22	.22	.88	2,980
Man with moderate muscular work	1.55	.28	.28	.99	3,520
Man at active muscular work	1.76	.33	.33	1.10	4,060

TABLE C.—*Prices used in estimating cost of daily dietaries.*

Articles.	Price per pound.	Articles.	Price per pound.	Articles.	Price per pound.
Beef:	*Cents.*	Pork—Continued.	*Cents.*		*Cents.*
Neck	7	Ham	16	Cheese	16
Chuck	10	Salt pork	12	Potatoes, white	1¼
Shoulder	12	Sausage	12	Sweet potatoes	2
Sirloin	20	Fish:		Turnips	2
Rump	16	Mackerel	12	Sugar	5
Round	14	Whole cod	8	Beans	5
Liver	10	Dry salt cod	7	Corn meal	2½
Dried beef	25	Salt mackerel	12	Oatmeal	5
Mutton:		Canned salmon	15	Wheat flour	2½
Shoulder	12	Lobster	12	Graham flour	3
Leg	18	Eggs, 24 cents per dozen	14	Wheat bread	4
Loin	20	Milk, 7 cents per quart	3½	Rice	7
Pork:		Butter	30	Canned corn	16
Loin	16				

TABLE D.—*Daily dietaries—Food materials furnishing approximately the 0.28 pound of protein and 3,500 calories of energy of the standard for daily dietary of a man at moderate muscular work.—Cost estimated from prices given in Table C.*

Food materials.	Amount.	Cost.	Nutrients.				Fuel value.
			Total.	Protein.	Fats.	Carbohydrates.	
I.	*Ounces.*	*Cents.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Calories.*
Beef, round steak	13	11.40	.26	.14	.12	....	695
Butter	3	5.65	.16	....	.16	....	680
Potatoes	6	1.25	.17	.02	....	.15	320
Bread	22	5.50	.89	.12	.02	.75	1,760
	44	23.80	1.48	.28	.30	.90	3,455
II.							
Pork, salt	4	3	.21	....	.21	....	880
Butter	2	3.75	.11	....	.11	....	450
Beans	16	5	.84	.23	.02	.59	1,615
Bread	8	2	.33	.04	.01	.28	610
	30	13.75	1.49	.27	.35	.87	3,585
III.							
Beef, liver	9	5.65	.17	.12	.03	.02	375
Butter	3	5.65	.16	....	.16	....	780
Milk, ½ pint	8	1.75	.06	.02	.02	.02	165
Corn meal	12	1.85	.63	.07	.03	.53	1,230
Bread	12	3	.50	.07	.01	.42	965
	44	17.90	1.52	.28	.25	.99	3,515
IV.							
Beef, sirloin steak	12	15	.25	.12	.13	....	725
Butter	3	5.65	.16	....	.16	....	680
Milk, 1¾ pints	28	6.15	.22	.06	.08	.08	570
Potatoes	12	.95	.12	.01	....	.11	240
Flour	12	1.85	.65	.08	.01	.56	1,235
	67	29.60	1.40	.27	.38	.75	3,450
V.							
Ham	12	12	.37	.11	.26	....	1,300
Pork, salt	½	.35	.03	....	.03	....	110
Butter	1	1.90	.05	....	.05	....	225
Potatoes	8	.65	.09	.01	....	.08	160
Beans	5	1.55	.27	.07	.01	.19	505
Flour	12	1.85	.65	.08	.01	.56	1,235
	38½	18.30	1.46	.27	.36	.83	3,535
VI.							
Beef, neck	10	4.40	.19	.10	.09	....	550
Butter	1	1.90	.05	....	.05	....	225
Milk, 1 pint	16	3.50	.13	.04	.04	.05	325
Potatoes	16	1.25	.17	.02	....	.15	320
Oatmeal	4	1.25	.23	.04	.02	.17	460
Bread	16	4	.67	.09	.02	.56	1,280
Sugar	3	.95	.19	....	....	.19	345
	66	17.25	1.63	.29	.22	1.12	3,505

Table D.—*Daily dietaries—Food materials furnishing approximately the 0.28 pound of protein and 3,500 calories of energy, etc.*—Continued.

Food materials.	Amount.	Cost.	Nutrients.				Fuel value.
			Total.	Protein.	Fats.	Carbohydrates.	
VII.	*Ounces.*	*Cents.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Calories.*
Beef, shoulder	8	6	.16	.09	.07		450
Salmon, canned	4	3.75	.10	.05	.05		245
Butter	2½	4.70	.13		.13		565
Milk, 1½ pints	24	5.25	.18	.05	.06	.07	485
Potatoes	8	.65	.09	.01		.08	160
Oatmeal	2	.65	.11	.02	.01	.08	230
Flour	10	1.55	.55	.07	.01	.47	1,030
Sugar	3	.95	.19			.19	345
	61½	23.50	1.51	.29	.33	.89	3,510
VIII.							
Beef, chuck	10	6.25	.22	.09	.13		800
Ham	6	6	.19	.06	.13		650
Two eggs	3	4	.05	.03	.02		135
Butter	2	3.75	.11		.11		450
Milk, 1 pint	16	3.50	.13	.04	.04	.05	325
Potatoes	12	.95	.12	.01		.11	240
Flour	8	1.25	.44	.05	.01	.38	825
Sugar	1	.30	.06			.06	115
	58	26	1.32	.28	.44	.60	3,540
IX.							
Beef, sirloin steak	8	10	.17	.08	.09		485
Mutton chops	5	6.25	.14	.04	.10		465
Butter	2	3.75	.11		.11		450
Milk, 1½ pints	24	5.25	.18	.05	.06	.07	485
Potatoes	8	.65	.09	.01		.08	160
Oatmeal	3	.95	.17	.03	.01	.13	345
Bread	12	3	.50	.07	.01	.42	965
Sugar	2	.65	.12			.12	230
	64	30.50	1.48	.28	.38	.82	3,585
X.							
Beef, neck	12	5.25	.22	.12	.10		660
Lobster	8	6	.03	.03			65
Butter	3	5.65	.16		.16		680
Milk, 1 pint	16	3.50	.12	.03	.04	.05	325
Potatoes	8	.65	.09	.01		.08	160
Oatmeal	2	.65	.12	.02	.01	.09	230
Bread	12	3	.50	.07	01	.42	960
Sugar	4	1.25	.25			.25	460
	65	25.95	1.49	.28	.32	.89	3,540
XI.							
Beef, dried	3	4.70	.06	.05	.01		140
Mutton leg	10	11.25	.19	.09	.10		580
1 egg	1½	2	.02	.01	.01		70
Butter	3	5.65	.16		.16		680
Milk, ¾ pint	12	2.65	.09	.02	.03	.04	245
Potatoes	8	.65	.09	.01		.08	160
Oatmeal	3	.95	.17	.03	.01	.13	345
Bread	10	2.50	.42	.06	.01	.35	800
Sugar	4	1.25	.25			.25	460
	54½	31.60	1.45	.27	.33	.85	3,480
XII.							
Beef, round steak	8	7	.16	.09	07		425
Cod, dried	2	.90	.03	.03			40
1 egg	1½	2.00	.02	.01	.01		70
Butter	3	5.65	.16		.16		680
Milk, 1¼ pints	20	4.40	.15	.04	.05	.06	405
Potatoes	8	.65	.09	.01		.08	160
Oatmeal	2	.65	.12	.02	.01	.09	230
Flour	10	1.55	.55	.07	.01	.47	1,030
Sugar	4	1.25	.25			.25	460
	58½	24.05	1.53	.27	.31	.95	3,500
XIII.							
Sausage	4	3	.14	.03	.11		510
Cod, whole	14	7	.07	.07			140
Butter	2	3.75	.11		.11		450
Milk, 1 pint	16	3.50	.13	.04	.04	.05	325
Beans	5	1.55	.26	.07	.01	.18	505
Rice	2	.90	.11	.01		.10	205
Sweet potatoes	16	2	.24	.01		.23	420
Bread	8	2	.33	.04	.01	.28	640
Sugar	3	.95	.19			.19	345
	70	24.65	1.58	.27	.28	1.03	3,540

TABLE D.—*Daily dietaries—Food materials furnishing approximately the 0.28 pound of protein and 3,500 calories of energy, etc.*—Continued.

Food materials	Amount.	Cost.	Nutrients.				Fuel value.
			Total.	Protein.	Fats.	Carbohydrates.	
XIV.	*Ounces.*	*Cents.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Calories.*
Beef, rump	6	6	.17	.05	.12		590
Mackerel	12	9	.10	.07	.03		280
Butter	2	3.75	.11		.11		450
Cheese	1	1	.04	.02	.02		130
Milk, 1 pint	16	3.50	.13	.04	.04	.05	325
Potatoes	8	.65	.09	.01		.08	160
Oatmeal	1	.30	.05	.01		.04	115
Flour (wheat)	8	1.25	.44	.05	.01	.38	825
Flour (Graham)	4	.75	.21	.03		.18	405
Sugar	2	.65	.12			.12	230
	60	26.85	1.46	.28	.33	.85	3,510
XV.							
Beef, shoulder	9	6.75	.18	.10	.08		515
Ham	6	6	.19	.06	.13		655
One egg	1½	2	.02	.01	.01		70
Butter	1½	2.80	.08		.08		340
Milk, ½ pint	8	1.75	.06	.02	.02	.02	165
Potatoes (white)	8	.65	.09	.01		.08	160
Sweet potatoes	8	1	.12	.01		.11	210
Corn meal	8	1.25	.42	.05	.02	.35	825
Bread	4	1	.16	.02		.14	320
Sugar	2	.65	.12			.12	230
	56	23.85	1.44	.28	.34	.82	3,490
XVI.							
Beef, chuck	8	5	.18	.08	.10		560
Mackerel, salt	4	3	.08	.04	.04		230
Two eggs	3	4	.05	.03	.02		135
Butter	2½	4.70	.13		.13		565
Cheese	1	1	.04	.02	.02		130
Milk, 1 pint	16	3.50	.13	.04	.04	.05	325
Potatoes	8	.65	.09	.01		.08	160
Rice	2	.90	.11	.01		.10	205
Bread	9	2.25	.38	.05	.01	.32	720
Sugar	1½	.45	.09			.09	175
	55	25.45	1.28	.28	.36	.64	3,205
XVII.							
Ham	8	8	.24	.07	.17		870
Cod, dried	4	1.75	.02	.02			50
Three eggs	4½	6	.07	.04	.03		200
Butter	1½	2.80	.08		.08		340
Cheese	1	1	.04	.02	.02		130
Milk, 1 pint	16	3.50	.13	.04	.04	.05	325
Potatoes (white)	6	.50	.07	.01		.06	120
Sweet potatoes	8	1	.12	.01		.11	210
Corn meal	8	2.50	.42	.05	.02	.35	825
Bread	4	1	.16	.02		.14	320
Sugar	2	.65	.12			.12	230
	63	28.70	1.47	.28	36	.83	3,620
XVIII.							
Pork chops, loin	8	8	.20	.07	.13		665
Liver	8	5	.15	.10	.03	.02	330
One egg	1½	2	.02	.01	.01		70
Butter	3	5.65	.16		.16		675
Milk, ½ pint	8	1.75	.06	02	.02	.02	165
Potatoes	12	.95	.12	.01		.11	240
Turnips	4	.50	.02			.02	35
Corn, canned	4	4	.07	01		.06	130
Oatmeal	1	.30	.06	.01	.01	.04	115
Rice	1	.45	.05			.05	100
Flour (wheat)	4	.65	.22	.03		.19	410
Flour (Graham)	2	.40	.11	.02		.09	205
Sugar	3	.95	.19			.19	345
	59½	30.60	1.43	.28	.36	.79	3,485

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Applications for bulletins of this series should be addressed to the Secretary of Agriculture, Washington, D. C.

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Farmers' Bulletin No. 22. Feeding Farm Animals. [In preparation.]

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 24.

AGRICULTURAL EXPERIMENT STATION,
FEB 14 1898
UNIVERSITY OF ILLINOIS.

HOG CHOLERA AND SWINE PLAGUE.

BY

D. E. SALMON, D. V. M.,
CHIEF OF THE BUREAU OF ANIMAL INDUSTRY.

[Issued December, 1894.]

WASHINGTON:
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1894.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., November 10, 1894.

Sir: I have the honor to transmit herewith for publication as a Farmers' Bulletin an article on "Hog Cholera and Swine Plague." The annual losses from these two diseases to the farmers of this country are variously estimated from $10,000,000 to $25,000,000. It is the object of this bulletin to tell the farmer how to identify these diseases, how to treat them, and how to prevent them; and it is believed that such information, presented in a concise and systematic manner, will prove of great value to the swine-growers of this country.

Respectfully,

D. E. Salmon,
Chief of Bureau of Animal Industry.

Hon. J. Sterling Morton,
Secretary.

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HOG CHOLERA AND SWINE PLAGUE.

INTRODUCTORY.

The annual losses from hog cholera in the United States are unquestionably very heavy, for, although all diseases of swine are called cholera by people not familiar with them, scientific investigation has confirmed the opinion of our farmers that we have a widespread and destructive plague to which the term hog cholera may be appropriately applied. The researches of the Bureau of Animal Industry, conducted in the most thorough and systematic manner and with the aid of all the appliances of modern science, have shown that there is another disease, called swine plague, which appears to be almost as common and fatal as hog cholera.

These two diseases resemble each other very closely in their symptoms, and it requires an examination of the internal organs after the animal's death, and in many cases a microscopical study, to clearly distinguish between them. Fortunately, we are able to formulate methods for the prevention, cure, and eradication of these diseases which may be applied with the same success to both. Hog cholera and swine plague are not only similar in symptoms, but in their effect upon the bodies of the affected animals. They resemble each other in that both are caused by bacteria; they must be combated by measures which will prevent exposure to these bacteria or destroy them after they have been introduced upon the premises, and the sick animals must be treated by remedies which will reduce the fever, stop the multiplication of the germs, and assist the affected organs in resuming their normal functions.

The difficulty of distinguishing between the two diseases is, therefore, of no great consequence in the practical work of controlling them. It is important to know that one or the other of these maladies is present, because this knowledge leads at once to the adoption of the measures applicable to the treatment of infectious diseases. Knowing that we have either hog cholera or swine plague to deal with, we are safe in carrying into effect the treatment recommended in this bulletin, because the agents which destroy one of these germs will generally destroy the other.

There are other infectious diseases which sometimes attack hogs, but they have either not been introduced into this country or have never approached in their destructive characters the two diseases named. The erysipelas of the continent of Europe appears to be the most fatal of the swine diseases in the countries where it is known. It has, however, never been recognized in America and probably has never been introduced on this continent. A few years ago it was proposed by enthusiastic though reckless investigators to introduce the virus of erysipelas as a vaccine for the prevention of hog cholera. The investigations of the Bureau showed, however, that the diseases were not similar; that hog cholera could not be prevented by the vaccine of erysipelas; and that the only effect of the proposed measure would be the introduction of a new plague, probably as destructive as the dreaded hog cholera.

This incident is referred to because it is one of the clearest illustrations we could have of the value of the scientific investigations conducted by the Government and the necessity of an official institution in this country competent to give advice on such important questions. These diseases can only be managed in the light of a thorough knowledge of their nature and characters; otherwise, the chances are that efforts for their suppression will lead to harm rather than to beneficial results.

There is a disease known as anthrax which may attack all species of warm-blooded animals and sometimes affects the hogs in limited areas of this country. This disease does not spread from farm to farm with the rapidity nor to anything like the distance that is common with hog cholera. When it exists, cattle and sheep, and often horses, are also affected; and the hogs usually contract it from eating the carcasses of animals that have died with it. Anthrax is confined to certain regions of the country, and is seen in those regions year after year. It is not a common disease with hogs.

These are about the only diseases liable to be mistaken for hog cholera and swine plague, and as one of them has never been seen in this country, and as the other is infrequent and more often affects other species of animals, it is plain that any contagious disease confined to swine which breaks out in this country is in all probability either hog cholera or swine plague.

GENERAL CHARACTERS.

Hog cholera and swine plague are both very fatal and destructive. They affect hogs in all parts of the United States, and cause heavy losses, which have been estimated to reach from $10,000,000 to $25,000,000 annually.

Owing to the resemblance in the features of the two diseases and the impossibility of distinguishing between them except by scientific investigation, we can not say what proportion of this loss should be ascribed to one disease and what to the other. Both diseases are known to be common, and both spread by infection.

Hog cholera is particularly fatal to young pigs, and often attacks them when the old hogs escape. The older animals have a greater power of resistance to the virus, and this power, which is also known as immunity, is increased when hogs have been exposed and only so slightly infected that they have recovered after an illness of some duration, or without showing any evident symptoms of the disease. In other words, if hog cholera breaks out among a herd of swine and is checked and apparently eradicated by medical treatment, the hogs that are saved are capable of resisting the contagion on the premises, while purchased hogs that have not been exposed will, when put with the others, contract the disease and die. This shows that the virus has remained upon the premises and the hogs have been saved not by the destruction of the contagion, but by keeping the infected hogs alive until they became immune. This is an important fact, and one which should be kept constantly in mind in applying measures of prevention.

The virus of hog cholera is more tenacious, more resisting to the conditions which affect the vitality of bacteria than that of swine plague, and it is also more easily spread and communicated to healthy animals. Swine contract hog cholera by taking the virus into the body with the food or drink, by inhaling it with the air, and less frequently by its gaining entrance through the surface of a fresh wound. On the other hand, the virus of swine plague is generally, if not always, taken into the lungs with the inhaled air.

The time that elapses between infection and the appearance of the first symptoms of illness, known as the period of incubation, varies from four to twenty days. During this period the germs are multiplying slowly and are gradually overcoming the vital powers of the animal by means of poisonous substances which they produce as the result of their growth.

SYMPTOMS.

The symptoms of serious diseases of swine are not as characteristic as with the larger animals. In the most acute and most severe cases the animals die very suddenly, either before sickness has been observed or after they have been ill but a few hours. Such cases are seen most frequently when the disease first appears in a herd. In the greater number of cases the progress of the malady is slower, and there is consequently a much better opportunity to observe the symptoms. There is first seen the signs of fever, shivering, unwillingness to move, more or less loss of appetite, elevation of temperature which may reach 106° to 107° F.; the animals appear stupid and dull, and have a tendency to hide in the litter or bedding and remain covered by it. The bowels may be normal or constipated at the beginning of the attack, but later there is generally a liquid and fetid diarrhea, abundant, exhausting, and persisting to the end. The eyes are at first congested and watery, but soon the secretion thickens, becomes yellowish, accumulates in the angles and gums the lids together. The breathing is more rapid that usual and may be oppressed and labored in the later stages. There is a cough, which, however, is not very frequent, and generally heard when the animals are driven from their bed. It may be a single dry cough, or it may be paroxysmal. The skin is often congested and red over the abdomen, inner surface of the limbs, under surface of the neck, and on the ears. The color varies from a pinkish red to dark red or purple. An eruption is sometimes seen, which leaves crusts or scabs of various sizes over the skin. There is rapid loss of flesh, the animal grows weak, stands with arched back and the abdomen drawn up, and walks with a tottering, uncertain gait. There is less and less inclination or ability to move, and the weakness and exhaustion increase until death results.

The symptoms of swine plague in many cases are not noticeably different from those of hog cholera. Frequently, however, the lungs are extensively inflamed in swine plague, and in that condition the breathing is more oppressed and labored, and the cough more frequent and painful.

The course of these diseases varies from one or two days to two or three weeks.

APPEARANCES ON POST-MORTEM EXAMINATION.

The germs of hog cholera have a habit of collecting or growing in clumps in the blood vessels, which leads to a plugging of the smaller vessels, with frequent rupture and escape of blood. This causes red spots where the blood leaves the vessels and collects in the solid tissues. These spots are variously referred to as petechiæ, ecchymoses, hemorrhages, and extravasations of blood. They are common in hog cholera for the reason given. In swine plague the bacteria are evenly diffused through the blood, never form plugs, and therefore hemorrhages from this cause are not seen.

In the most acute forms of hog cholera the changes seen in the various organs consist principally of these red spots caused by hemorrhages of greater or less extent.

The spleen is generally enlarged to from two to four times its normal size, is soft, and engorged with blood.

The blood extravasations are frequent in the lymphatic glands; beneath the serous membranes of the thorax and abdomen, and particularly along the intestines; on the surface and in the substance of the lungs and kidneys; on the mucous surface of the stomach and intestines; and in the connective tissue beneath the skin. The contents of the intestines are sometimes covered with clotted blood.

The diseases of Europe which appear very closely related to our swine plague (*schweineseuche*, *wildseuche*) also have a hemorrhagic form, but this has not been observed in America, although hemorrhagic inflammation of the stomach and intestines has been seen in swine plague. Cases of swine plague with external swellings caused by an infiltration of yellow lymph in the subcutaneous connective tissue, generally of the neck, have been seen, but are rare in this country.

The subacute and chronic forms of hog cholera and swine plague are more common. In this form of hog cholera the principal changes are found in the large intestine and consist of ulcers which appear as circular, slightly projecting masses varying in color from yellowish to black. Occasionally these ulcers are slightly depressed and uneven in outline. When cut across, they are found to consist of a firm, solid growth extending nearly through the intestinal wall. They are most frequent in the cæcum, upper half of the colon, and on the ileo-cæcal valve.

In the chronic form of the disease the spleen is rarely enlarged; the lymphatic glands of the affected intestine are enlarged and tough. In the more acute cases lung lesions may be found, varying from collapse and œdema of the lung tissue to broncho-pneumonia.

In swine plague the lungs are often found inflamed, and to contain large numbers of small points, which may be made out by loss of color, where the life of the tissue has been destroyed (necrotic foci). There may be also found in the lungs large cheese-like masses from 1½ to 2 inches in diameter. Inflammation of the serous membranes is very common in swine plague, and this may be found affecting the pleura, pericardium, and peritoneum, accompanied with fibrinous, inflammatory deposits on the surface of these membranes. There may be congestion of the mucous membrane of the intestines, particularly of the large intestine; or the disease in this region may be more intense and lead to a croupous inflammation with the formation of a fibrinous exudative deposit on the surface.

In hog cholera the first effect of the disease is believed to be upon the intestines, with secondary invasion of the lungs. In swine plague the first effect is believed to be upon the lungs, and the invasion of the intestines a subsequent process.

Briefly reviewing these changes, we find that the most characteristic lesions of hog cholera consist of:

(1) Hemorrhages, particularly in the subcutaneous, submucous, and subserous connective tissue; in the lymphatic glands, and in the various organs of the body.

(2) Ulcerations of the large intestines.

(3) Collapse of lung tissue, and, less frequently, broncho-pneumonia.

The most characteristic lesions of swine plague are:

(1) Inflammation of lungs; numerous small necrotic points in these organs, or a few larger cheesy masses.

(2) Inflammation of serous membranes with fibrinous deposits.

(3) Congestion of mucous membrane of intestine, or inflammation of the same with fibrinous deposits.

Notwithstanding this clear difference in typical cases, there are many outbreaks where it is difficult to make a diagnosis even after post-mortem examination, because both diseases may be affecting the same animal at the same time, or the changes may resemble both diseases without being very characteristic of either. In such cases it is only by microscopic examination and cultivation of the germs that a reliable diagnosis can be made.

THE CAUSE OF THESE DISEASES.

Both hog cholera and swine plague are caused by bacteria, which have now been so carefully studied that they may be easily identified by persons accustomed to bacteriological researches. The hog-cholera germs are slightly larger and more elongated than those of swine plague; they are provided with flagella, or long thread-like appendages, which enable them to move rapidly in liquids; while the swine-plague germs have no such organs, and are unable to move except as they are carried by the liquid in which they float.

Hog-cholera bacteria, when inoculated in minute doses, are fatal to mice, rabbits, and guinea pigs, and in large doses may kill pigeons. Swine-plague germs are fatal to these animals and also to fowls.

Hog cholera may be produced experimentally (1) by exposing well hogs to diseased ones in the same pens; (2) by feeding the internal organs of diseased carcasses or cultures of the germs; (3) by hypodermic injection of cultures of the germs in doses of one-half to 1 cc. or greater.

Swine plague may be produced experimentally (1) by cohabitation; (2) by injecting cultures of the germs into the lung tissue.

In some outbreaks the swine-plague germs may produce the disease if they are injected hypodermically, but as a rule the swine plague of this country can not be communicated in that way. Cultures of the bacteria of swine plague have been fed to hogs, and have been sprayed into the air which they were breathing, without causing the disease.

Both diseases are produced by injecting cultures of their respective germs directly into the blood vessels.

From the results of experiments with these diseases it has been concluded that the germs of hog cholera find their way into the bodies of swine principally with the food and drink and with the inspired air; while those of swine plague are taken almost entirely with the air, or, at least, they almost invariably gain entrance through the lungs.

Hog-cholera germs are very hardy and vigorous. They are able to multiply and live for a long time in the water of ponds and streams; they may live in the soil for at least three months, and in accumulations of straw and litter for a much longer time; they withstand drying and other adverse conditions in a remarkable manner.

The swine-plague germs, on the contrary, are very delicate and easily destroyed. They soon perish in water or by drying; the temperature for their growth must be more constant and every condition of life more favorable than is required for the hog-cholera germs. The swine-plague germs are widely distributed in nature and are probably present in all herds of swine, but they are not deadly to these animals except when their virulence has been increased or the resistance of the animals diminished by some unusual conditions. The hog-cholera germs, on the contrary, are not usually present and must be introduced from infected herds before this disease can be developed. The swine-plague germs may acquire sufficient virulence, by encountering proper conditions on one farm, to spread to adjoining farms in the same manner as hog cholera. There are, hence, practically the same conditions to guard against in the prevention of the two diseases.

DIAGNOSIS.

The first question that occurs to the owner of swine when disease appears among his animals is, What is the disease with which they are affected? It is important to briefly consider in this place the nature of the evidence upon which this question is to be answered.

If several animals are affected with the symptoms already enumerated, and if the same disease has been affecting the hogs on neighboring farms, we may decide that one or both of the diseases in question are present, since no other epizootic disease has been recognized in this country.

In anthrax districts there may be occasional small outbreaks of that disease, in which there is great inflammation and swelling of the tongue (glossanthrax), or of the throat (anthrax angina), or simply a fever with no local swellings. If the disease is anthrax, other species of animals, horses, cattle, and sheep, will also be affected.

If, on examining the carcass after death, projecting button-like ulcers are found in the large intestines, we know that hog cholera is present. It must be remembered, however, that these ulcers are not found in the most acute cases, but only in the subacute or chronic form of the disease where life is prolonged a sufficient time for them to form.

If there is inflammation of the lungs and particularly if cheese-like masses are found in the substance of these organs, the disease is probably swine plague.

Small blood spots in the tissues or scattered over the internal organs indicate hog cholera, while inflammation of the serous membranes indicates swine plague.

A bacteriological examination is the final test, but neither this nor inoculation experiments are available to the farmer, for whose use this bulletin is prepared.

PROGNOSIS.

The losses which result from outbreaks of hog cholera and swine plague depend partly upon the condition of the hogs—that is, upon their susceptibility to the disease—and partly upon the virulence of the contagion in the particular outbreak. If the animals are very susceptible and the contagion very virulent, the loss even in large herds may reach 90 to 95 or even 100 per cent in those cases where the disease is allowed to run its course. In milder outbreaks or with animals more capable of resisting the contagion the losses vary from 20 to 60 per cent. Toward the end of an outbreak a larger proportion of animals will recover than at the beginning. A portion of those recovering will fatten, but others remain lean, stunted in their growth, or never become really healthy animals.

THE TREATMENT OF HOG CHOLERA AND SWINE PLAGUE.

Can hog cholera be cured? and, if so, what remedy will restore the diseased animals to health? These are the first questions asked by the swine-grower, and to his mind this should be the objective point of all investigations. With all diseases of this class, however, prevention is cheaper and in every way more satisfactory than medical treatment. The great aim of the Goverment and the farmers should be, therefore, to prevent the spread of infectious diseases. Every swine-grower should use the utmost precautions to prevent the introduction of these plagues into his herd. In spite of such preventive measures many herds will become infected. Until the Federal Government or the individual States enforce measures of eradication, it is, consequently, legitimate to ask and to answer the question as to the proper medical treatment.

Before formulating this treatment it should be explained that a remedy which will cure every case is not to be expected. There has never been discovered a remedy for a single one of the infectious diseases of man or animals which will cure every individual attacked. Some forms of these diseases are so violent and rapid that the animals are dead almost before they are observed to be sick. Under such conditions there is not time for the most active remedy to produce a beneficial effect.

In many outbreaks the type of the malady is less virulent and there is time to treat the animals after they are sick, and also the whole herd after some members of it have shown that they are diseased. For a long time after beginning the investigations of the infectious diseases of swine, the writer was doubtful if any remedy or combination of remedies could be made which would produce any marked effect. The experiments of the last year, however, indicate that treatment if properly applied may be successful. With the assistance of Dr. E. A. de Schweinitz, chemist of the Bureau, and Dr. V. A. Norgaard, inspector, a number of formulas have been developed and used in the field with good results.

The most efficacious formula which has been tried is the following:

	Pounds.
Wood charcoal	1
Sulphur	1
Sodium chloride	2
Sodium bicarbonate	2
Sodium hyposulphite	2
Sodium sulphate	1
Antimony sulphide (black antimony)	1

These ingredients should be completely pulverized and thoroughly mixed.

The dose of this mixture is a large tablespoonful for each 200 pounds weight of hogs to be treated, and it should be given only once a day. When hogs are affected with these diseases they should not be fed on corn alone, but they should have at least once a day soft feed, made by mixing bran and middlings, or middlings and corn meal, or ground oats and corn, or crushed wheat with hot water, and then stirring into this the proper quantity of the medicine. Hogs are fond of this mixture, it increases their appetite, and when they once taste of food with which it has been mixed they will eat it though nothing else would tempt them.

Animals that are very sick and that will not come to the feed should be drenched with the medicine shaken up with water. Great care should be exercised in drenching hogs or they will be suffocated. Do not turn the hog on its back to drench it, but pull the cheek away from the teeth so as to form a pouch, into which the medicine may be slowly poured. It will flow from the cheek into the mouth, and when the hog finds out what it is, it will stop squealing and swallow. In our experiments hogs which were so sick that they would eat nothing have commenced to eat very soon after getting a dose of the remedy, and have steadily improved until they appeared perfectly well.

This medicine may also be used as a preventive of these diseases, and for this purpose should be put in the feed of the whole herd. Care should of course be observed to see that each animal receives its proper share. In cases where it has been given a fair trial, it has apparently cured most of the animals which were sick and has stopped the progress of the disease in the herds. It also appears to be an excellent appetizer and stimulant of the processes of digestion and assimilation, and when given to unthrifty hogs it increases the appetite, causes them to take on flesh, and assume a thrifty appearance.

This is a résumé of the reports from the tests of this medicine during the last year, and while I should prefer, from a scientific point of view, to continue these experiments for another year before venturing to recommend it as a remedy for these diseases, the many urgent requests which have been made upon me for the formula lead me to give it in time for it to be tried by our farmers during the current year. Those who are interested in this subject are earnestly requested to try this mixture and report their results to this Bureau for the benefit of the hog-raising industry.

Success or failure with this remedy depends largely upon the manner in which it is used. If it is improperly administered, or the hogs left out in cold storms and compelled to remain day and night in mud six inches or a foot deep, under the necessity of searching through this mud to find an ear of corn in order to get anything to eat, the farmer might as well save his money and let his hogs die, as nothing which we have been able to find will save them under such conditions. If, on the other hand, the sick animals can be made reasonably comfortable, and given soft, easily digested food to eat, the medicine, of which we have just given the formula, may be used with confidence that it will give good returns for its cost and the trouble of its administration.

In treating hogs for these diseases it must not be forgotten that in nearly all cases there is more or less inflammation of the internal organs, and particularly of the stomach and intestines. To treat such diseases successfully the animals should be kept dry and comfortable, and where drafts of air will not blow upon them. The food must be such as can be digested by the irritated and inflamed organs which are charged with this function. With these general principles in mind the farmer may undertake to treat his sick hogs with a fair prospect of success. He may not save them all, but he should be able to preserve a good proportion of them.

The question now arises, What disposition should be made of the hogs during treatment, and what sanitary measures should be adopted in addition to the medical treatment? When the hogs are first found to be affected with hog cholera or swine plague the lot or pens where they have been confined should be disinfected by dusting plentifully with dry, air-slaked lime, or by sprinkling with a 5 per cent solution of crude carbolic acid. The animals should then all be moved to new quarters. If possible, the sick and apparently well should be separated before they are moved and then put into different lots. This is not essential, but it is an aid to the treatment. The hogs should be kept in dry lots, or pens, where there is no mud, and, *above all*, no stagnant water. It is well to keep these lots disinfected by the free use of air-slaked lime or carbolic acid.

It is not expected by this supplementary treatment that the hogs will be entirely removed from the influence and attacks of germs. This is not necessary. The number of germs which gain access to their bodies may be so reduced by following this plan, however, that the vital force of the system, assisted by the medicine, is sufficient to overcome them.

During this treatment the hogs gain a marked degree of immunity. No doubt this is the result of attacks of the disease from which they recover. This recovery is in spite of the continued infection of the premises, and even though the hogs which have gone through the outbreak are apparently well and thriving, new hogs added to the herd are liable to be attacked. For this reason five or six months should be allowed to pass before any new hogs are purchased and brought on the premises or before any are sold to be put among other lots of hogs. Young pigs born under such conditions in some cases are able to resist the infection, while in other cases they may suffer severely or die.

If any hogs die during the progress of the outbreak their carcasses should be immediately burned or deeply buried, and the places where they have lain or the ground over which they are dragged should be disinfected with carbolic acid or lime according to the method already mentioned.

SANITARY MEASURES TO PREVENT THE INTRODUCTION OF HOG CHOLERA AND SWINE PLAGUE.

The swine-grower should use every effort to prevent the introduction of the contagion of these diseases upon his premises. If he purchases hogs from a distance or sends his own animals for exhibition at the fairs, he should insist upon their being transported in clean cars, which have been disinfected if they have previously carried swine. When new hogs are brought upon the farm or when his own return from exhibition, they should be rigidly quarantined and not allowed to come in contact with the other hogs on the farm for at least six weeks.

Hogs should not be allowed to run at large in the vicinity of railroads over which swine are transported. Infected hogs are frequently shipped to market, and there are sufficient droppings from the cars in which they are carried to scatter the contagion along the railroad for the whole distance they travel.

When these diseases appear upon a neighboring farm precautions should be adopted to prevent the introduction of the contagion. No one should go upon the fields or into the pens where the sick animals are and then go to another farm where the disease has not appeared. Remember that a particle of manure or dirt the size of a mustard seed from an infected farm is sufficient to start an outbreak that will destroy a herd of swine. A particle of that size may be carried upon the shoes of a visitor, upon the foot of a dog or other animal, upon a wagon wheel, or in a multitude of other ways. Nonintercourse at such a time is therefore the safest rule.

Experience shows that hogs kept up in a pen or small lot are less subject to infection when cholera is in the neighborhood than those which are allowed to run at large or in the fields. It is, consequently, advisable, when there is reason to fear this disease, to keep the hogs in a small inclosure, which should be as dry as possible, and disinfected once a week with air-slacked lime or a 5 per cent solution of carbolic acid. A small quantity of carbolic acid (3 to 15 drops, according to age) in the drinking water tends to prevent infection and may have a beneficial influence upon the course of the disease.

PREVENTION OF DISEASE BY PROPER BREEDING AND FEEDING.

There is occasionally a herd of swine that does not contract hog cholera even though exposed to the contagion. Two herds may sometimes run together and be exposed to the same extent; one will be nearly or quite destroyed, while the other does not suffer. These facts naturally lead to the inquiry as to whether it is possible to so breed and feed hogs as to largely or entirely prevent the most common diseases. To what extent disease may be prevented in this way, we are not in a position to state, as we are not familiar with enough experiments to enable us to reach a conclusion. It is clear, however, that something can be accomplished in this way, and as the carrying out of the plan would also increase the hardiness and thriftiness of the swine it is certainly worthy of adoption.

The first principle of this method of prevention is to breed only from mature breeding stock which is only distantly or not at all related. The second principle is to select, if possible, animals for breeding stock which have shown, by having passed through an outbreak without becoming affected, that they possess a power of resisting hog cholera. The third principle is to feed the growing shoats upon a variety of food which will lead to normal and harmonious development of all the different organs. The application of these principles must be made by the individual breeder in accordance with his circumstances and surrounding conditions. The breeding from mature animals which are not closely related can be easily adopted by anyone. The selection of stock which has shown that it possesses a power of resisting the disease is much more difficult, and in many cases it will be impossible for the general farmer, though there are many breeders who could experiment in this direction.

The diet of corn alone, upon which the hogs of so large a part of the country are raised, has done more than anything else to weaken the vital powers of these animals. With wheat selling in the markets of the country as low as corn, there is no longer any excuse for limiting the food of hogs to a single grain. Wheat is much better than corn for growing animals, but should be crushed or rolled to give the best results. Ground oats, middlings, bran, and pease may also be used to give variety. It is hardly necessary to add that during the warm months of the year hogs should have plenty of young grass or clover.

By intelligently applying these principles in the production of the breeding stock a strain of animals may be developed which is hardy, vigorous, prolific, and much more capable of resisting disease than is the ordinary inbred and corn-fed stock which is now so generally used by the farmers of this country.

This bulletin is prepared for the practical use of the farmer; it is intended to be suggestive rather than exhaustive; it contains the important points necessary for identifying and controlling the infectious diseases of swine. If its teachings are intelligently and thoroughly followed the losses from these diseases may be greatly reduced. Experience having demonstrated that such beneficial results are possible, it has been deemed best to present this information in a condensed and popular form.

FARMERS' BULLETINS.

These bulletins are sent free of charge to any address upon application to the Secretary of Agriculture, Washington, D. C.

[Only the bulletins named below are available for distribution.]

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No. 53. How to Grow Mushrooms. Pp. 20.
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No. 55. The Dairy Herd: Its Formation and Management. Pp. 24.
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No. 57. Butter Making on the Farm. Pp. 15.

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U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 25.

AGRICULTURAL EXPERIMENT STATION,
FEB 11 1898
UNIVERSITY OF ILLINOIS.

PEANUTS: CULTURE AND USES.

BY

R. B. HANDY,
Of the Office of Experiment Stations.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., December 15, 1894.

Sir: I have the honor to transmit herewith for publication as a Farmers' Bulletin an article on the culture and uses of peanuts, prepared under my direction by Mr. R. B. Handy, special agent assigned to this Office. Attention has recently been drawn to this crop because of attempts made to introduce peanut meal as an article of human food. It has also been urged that the manufacture of peanut oil in this country might be greatly extended. Present conditions do not, however, seem to warrant any considerable increase in the acreage of the crop. With this, as with other crops, the effort should rather be made to increase the average yield per acre by more careful cultivation and a proper rotation of crops. More attention should also be given to the utilization of the nutritive forage which the peanut plant affords. It is probable that in many localities peanuts might be profitably introduced and grown on a small scale as part of a diversified system of agriculture, with special reference to the use of the vines as food for farm animals. In the present bulletin methods of culture are described and the composition of the different products is given, with explanations of the nature and extent of their use for various purposes.

Respectfully,

A. C. True, *Director.*

Hon. J. Sterling Morton,
Secretary of Agriculture.

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PEANUTS: CULTURE AND USES.

DESCRIPTION AND HISTORY.

The peanut (*Arachis hypogæa*), known also in different localities as the earthnut, groundnut, ground pea, goober, and pindar, is a trailing, straggling annual, growing from 1 to 2 feet high, with thick, angular, pale-green, hairy stems, and spreading branches, and has the peculiar habit of maturing its fruit underground. Strictly speaking it is not a nut at all, and should more properly be called the ground pea. Its blossom is at the end of a long pedicel-like calyx tube, the ovary being at the base. After the fall of the flower the peduncle, or "spike," elongates and bends downward, pushing several inches into the ground, where the ovary at its extremity begins to enlarge and develops into a pale yellowish, wrinkled, slightly curved pod, often contracted in the middle, containing from 1 to 3 seeds. Should the "spike" by accident not be enabled to thrust its point in the ground within a few hours after the fall of the flower it withers and dies. When fully grown the pods are from 1 to 2 inches long, of a dusky yellowish color, with a netted surface.

More or less abundantly scattered over the roots of the peanut plant, as well as those of other members of the same family, are warts of about the size of a pin head, or larger (see Fig. 1, p. 7). These tubercles, as they are usually called, play a very important part in the life history of the plant. Within them, while in a fresh or growing state, may be seen, by the aid of a good microscope, myriads of very minute organisms. These bacteria-like bodies live partly on the substance supplied from the roots, and at the same time they take from the air and elaborate for the use of the plant considerable quantities of nitrogen. Nitrogen is the most expensive element that must be supplied to plants in fertilizers. The organisms living in these porous tubercles take it abundantly from the air, of which it comprises about five-sixths, and supply it to the plant without any cost. In this way a total amount of nitrogen is often acquired by the plant far in excess of the amount analyses show to be present and available in the soil. For this reason were the peanut cultivated as a green crop and turned under in the ground (like clover and cowpeas—species of the same family) it would improve the soil rather than exhaust its fertility, as under the present method of culture.

Like many other extensively cultivated plants, the peanut has not been found in a truly wild state, and hence it is difficult to fix upon its habitat. So widely has it been cultivated in eastern countries that some botanists have attempted to trace its spread from China to Japan, thence through the East India Islands to India, and thence to Africa, where in the seventeenth century it was so extensively cultivated and had become such an important article of native food that the slave dealers loaded their vessels with it, using it as food for their cargoes of captives. But the weight of authority seems to be in favor of accepting it as a native of Brazil, thus adding the peanut to the four other plants of commercial importance that America has contributed to the agriculture of the world, namely, cotton, Indian corn, potato, and tobacco. Though it may be a native of the Western Continent, it early became a largely cultivated plant in the warmer portions of the Old World, occupying a distinct place in the agriculture of those countries long before its merits were recognized in the land of its origin.

While the peanut has been cultivated in the United States to a limited extent for a number of years, it is only since 1866 that the crop has become of primary importance in the eastern section of this country, which seems peculiarly adapted to its production.

Between 1865 and 1870 the rapid spread of the culture of peanuts was phenomenal, due probably to the knowledge of them acquired by the individual members of the various armies which at one time or another occupied the eastern section of Virginia. Each year doubled and at times increased threefold its crop over that of the preceding year, so that this country, from being a large importer of west African nuts, was soon able to supply the domestic demand with the home-raised article.

Virginia, North Carolina, and Tennessee produce a large part of the peanut crop of the United States. This is due, possibly, to the fact that their soil and climate are admirably adapted to the successful cultivation of this plant, and also, no doubt, because of the large profits which the farmer was able to secure from the culture of peanuts at a time when other agricultural industries were in a very depressed condition. Within the last few years this crop has ceased to be as profitable as heretofore. The method of culture—the annual planting of nuts on the same land, the lack of proper rotation of crops, the complete removal of all vegetation from the land, and the failure to replenish the soil by means of fertilizers—has been a great factor in reducing the profits of the crop by reducing the ability of the land to produce such crops as were previously secured in that section, so that now instead of an average of 50 bushels per acre, with frequent yields of over 100 bushels, the average in the peanut section is not over 20 bushels, while the cost of cultivation has been but slightly reduced.

COMPOSITION.

The composition of the different parts of the peanut plant, from the standpoint both of food and fertilizing value, is shown in the following tables, compiled from the most reliable data at hand. The results in the case of food constituents are calculated to a uniform water-free basis in order to admit of a fair comparison. It must be kept in mind that all of the substances in their original condition contained variable but considerable amounts of moisture, and if allowance is made for this moisture the percentages of the food constituents will be lower than those reported in the tables. The first column shows the percentages of moisture given in the original reports of analyses.

Food constituents in different parts of the peanut plant.

	Water.	In water-free substance.					
		Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.	Nitrogen.
Peanut kernels:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Alabama peanuts	10.88	4.26	35.37	2.66	19.33	55.37	5.50
Tennessee crop, 1888	3.87	2.40	28.65	2.37	17.23	49.35	4.58
Tennessee crop, 1889	4.86	2.51	27.07	2.52	19.30	48.60	4.33
Georgia peanuts	12.85	2.18	30.49	2.34	21.86	43.13	4.88
Spanish peanuts (grown in Georgia)	13.15	2.72	32.18	3.50	20.43	41.17	5.15
Egyptian peanuts	......	2.85	22.97	1.61	20.27	52.30	3.67
Bombay peanuts	7.71	3.32	33.73	2.33	10.15	50.47	5.40
Congo peanuts	5.01	2.73	28.33	1.55	14.51	52.88	4.53
Rufisque peanuts (West African)	4.59	2.53	29.73	1.24	14.02	52.48	4.76
Japanese peanuts (Nankin-mame)	15.61	1.93	32.66	4.88	5.99	54.54	5.23
Japanese peanuts (Tojin-mame)	7.50	1.95	26.49	4.32	12.64	54.60	4.24
Average of all available analyses	7.85	2.77	29.47	4.29	14.27	49.20	4.67
Peanut vines (with leaves):							
Japanese, green	77.10	7.05	16.00	20.11	50.01	4.27	2.56
Spanish, cut before blooming	32.62	9.96	12.69	24.75	46.30	6.30	2.03
Georgia, cut before blooming	29.78	11.32	12.57	19.89	50.38	5.84	2.01
Average of last two	31.20	10.64	12.63	22.32	48.34	6.07	2.02
Spanish, cut when fruit was ripe	31.43	11.24	11.71	28.46	43.77	4.82	1.87
Georgia, cut when fruit was ripe	32.38	12.91	9.91	36.10	35.86	5.22	1.58
Average	31.91	12.08	10.81	32.28	39.81	5.02	1.73
Peanut hay, Tennessee crop	7.83	17.04	11.75	22.11	46.95	1.84	1.88
Peanut vines (without leaves), Egyptian	......	8.80	6.25	32.95	49.49	2.50	1.00
Peanut leaves, Egyptian	......	10.90	10.00	21.51	54.09	3.50	1.60
Peanut roots, Egyptian	......	6.65	8.75	23.50	59.10	2.00	1.40
Peanut roots, Spanish (Georgia crop)	29.62	9.75	8.78	41.66	35.50	4.31	1.40
Peanut roots, Georgia	28.74	9.58	7.63	48.59	31.00	3.20	1.22
Peanut hulls:							
Spanish peanuts (grown in Georgia)	19.20	4.63	7.19	71.78	14.32	2.08	1.15
Georgia peanuts	20.62	3.00	4.99	79.30	10.59	2.12	0.80
Tennessee crop, 1888	8.81	2.03	6.42	73.07	17.14	1.34	1.03
Tenneesee crop, 1889	7.81	3.63	7.94	65.81	20.45	2.17	1.27
Coarse ground (German analysis)	10.50	3.13	7.71	69.37	16.22	3.57	1.22
Fine ground (German analysis)	10.70	3.58	8.18	66.64	17.90	3.70	1.31
Egyptian peanuts	......	3.70	8.12	45.06	39.31	3.81	1.30
Average	12.94	3.39	7.22	67.29	19.42	2.68	1.17
Peanut shucks (inner coating of kernel)	10.80	5.72	25.11	20.96	26.89	21.52	4.00
Peanut meal (average of 2,785 analyses)	10.74	5.48	52.49	5.93	27.26	8.84	8.40

Fertilizing constituents in different parts of the peanut plant.

	In fresh or air-dry substance.					
	Water.	Nitrogen.	Phosphoric acid.	Potash.	Lime.	Total ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Peanut kernels	6.30	4.51	1.24	1.27	0.13	3.20
Peanut vines (cured)	7.83	1.76	0.29	0.98	2.08	15.70
Peanut hulls	10.60	1.14	0.17	0.95	0.81	3.00
Peanut cake (meal)	10.40	7.56	1.31	1.50	0.16	3.97

As regards food value these tables show that peanut kernels with an average of 29 per cent of protein, 49 per cent of fat, and 14 per cent of carbohydrates in the dry material take a high rank, and should be classed with such concentrated foods as soja beans, cotton seed, etc. The vines are shown to be superior to timothy hay as a feeding stuff, and but slightly inferior to clover hay. The food value of the hay is of course higher the greater the percentage of nuts left on the vines in harvesting. The hulls also appear to possess considerable value as a feeding stuff, being much richer in valuable food constituents (protein, fat, and carbohydrates) than cotton hulls, which are extensively used in some localities in the South as a coarse fodder, and about equal to the poorer grades of hay. The ground hulls are used to a considerable extent as a coarse fodder in European countries. Peanut meal (the ground residue from oil extraction) is a valuable feeding stuff, highly appreciated and extensively used in foreign countries. It contains, as the averages of over 2,000 analyses show, about 52 per cent of protein, 8 per cent of fat, and 27 per cent of carbohydrates, and is therefore one of the most concentrated feeding stuffs with which we are familiar, ranking with cotton-seed meal, linseed meal, etc., and in some cases ahead of them.

As regards fertilizing constituents, the tables show that the peanut, like other leguminous plants, is rich in nitrogen and contains considerable amounts of phosphoric acid and potash. The kernels are as rich in these constituents as the kernels of cotton seed and the vines are nearly as valuable as a fertilizer as those of cowpeas.

For the sake of completeness the fertilizing constituents of hulls and meal or cake are reported. It will be seen that the former are comparatively poor while the latter is quite rich, being nearly equal to cotton-seed meal as a fertilizer.

VARIETIES.

The Virginia running variety of the peanut, being most widely known and most popular with the trade, may be taken as the typical American peanut. Its vines are large, with spreading branches, growing flat on the ground and bearing pods over almost their entire length. The pods are large and white, weighing about 22 pounds to the bushel.

The Virginia bunch variety grows erect and fruits near the taproot, but produces pods very closely resembling those above described.

There are two varieties in Tennessee, the white and red, the white closely resembling the Virginia running variety and the red producing somewhat smaller pods with kernels having a dark red skin. This variety matures earlier than the white, yields fewer pops, or imperfect pods, has a less spreading habit, and on account of this difference in growth is perhaps somewhat more easily cultivated.

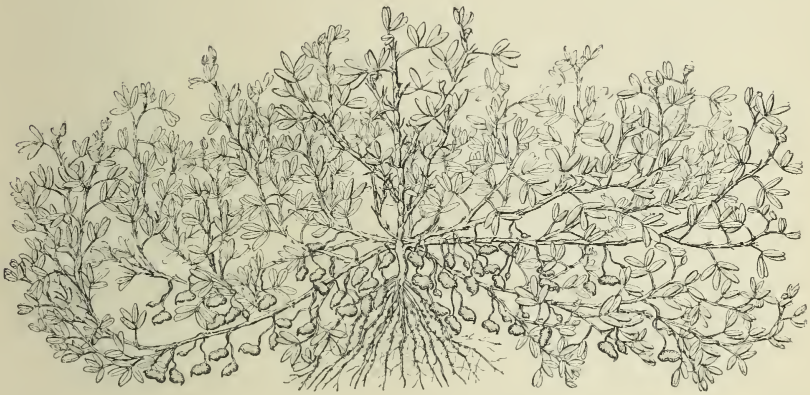

Fig. 1.—The Peanut plant (*Arachis hypogæa*)—Virginia running variety.

The North Carolina (or African) variety grown in the Wilmington section of the State has much smaller pods than those just described, weighing 28 pounds to the bushel, the kernels containing more oil than those of other varieties.

The Spanish variety has a relatively small, upright vine, forms small pods near the taproot, and can be planted much closer together than any of the others, thus producing a very heavy crop to the acre.

The North Louisiana Station found the Spanish a desirable variety, easily harvested, all of the peas adhering to the vine. It required a much shorter period to mature, and planted as late as July 1 matured a full crop in that latitude before frost. The pods filled out well, forming few if any pops.

The Georgia red nut, like the similar variety in Tennessee, has medium-sized vines growing up from the ground and fruiting principally near the taproot, with three or four kernels to the pod.

These comprise all the varieties cultivated in this country, but in Costa Rica there is a variety with long pods without division, containing four or five seeds, and in the Argentine Republic a large-sized variety with a deep orange-colored shell. In the Malay Archipelago there are two varieties, called the white and brown, resembling probably the white and red Tennessee varieties, except as to size.

The peanut of India and Africa resembles the North Carolina variety in size, and is raised principally for the oil which is contained in its kernels.

CLIMATE SUITABLE FOR PEANUT CULTURE.

While the peanut requires a climate in which there is a season of five months free from frost, it is not necessary that this should be a period of extreme heat, as the seeds form during cool weather in the latter part of summer and early autumn. (This fact has been developed by experiments with the crop during the past twenty-five or thirty years.) It was formerly supposed that being a native of intertropical countries and flourishing most luxuriantly in the warm, moist atmosphere of Brazil, India, and Africa, it would be impossible to successfully cultivate the peanut in the United States. Contrary to this view the attempt to cultivate it in North and South Carolina was successful, and step by step it extended northward until the fortieth parallel of latitude had been reached.

It is probable that on suitable soil the peanut will grow in any latitude where Indian corn will thrive, but whether it will be a profitable crop depends upon other considerations than its ability to withstand the climate. The most favorable weather for the peanut is an early spring, followed by a warm summer of even temperature, with moderate moisture and free from drought, and an autumn, or harvesting time, with very little precipitation, as rain injures the newly gathered vines and nuts. These climatic conditions are to be found on the Atlantic Seaboard from New Jersey southward, in the Mississippi Valley as far north as southern Wisconsin, and on the Pacific Coast south of the Columbia River. Again, it is probable that the quality of the nut depends upon climatic conditions, as it is true that the nuts grown in tropical countries contain much more oil than those of the same variety grown in temperate latitudes, so that the proposition has been laid down that the oil content of the nut is in inverse proportion to the distance from the equator. The nuts most in demand by the American trade are those raised between the parallels of 36° and 37½° north latitude, as they contain the least oil, therefore being better for use as human food.

SOIL SUITABLE FOR PEANUT CULTURE.

A sandy loam, neither too dry nor too sandy, yet light and porous, produces the most marketable peanuts, (because it is nearer the natural color of the peanut shell) and the trade for which American peanuts are raised demands a light-colored shell, but equally sound and well-flavored nuts may be produced on other soils. In fact, almost any soil that can be put in a friable condition and kept so will produce peanuts, provided it contains a sufficient quantity of lime.

As cultivation of the crop extends, and more land is needed, much of this crop will be planted in clayey soil, and the result will be heavier peanuts. Indeed, more pounds per acre may be grown upon stiff land than upon light soil, the chief objection to dark and tenacious soils being that they stain the pods.

Clayey soil is somewhat colder and more inert, and the planting on such soil would therefore be somewhat delayed in the spring. In more northern latitudes, where the season is short, this might cause the crop to be cut off by frost before maturity. There is an abundance of good peanut land all along the Atlantic Seaboard from New Jersey to Florida, and also in the Mississippi Valley, not yet used for the crop.

MANURING.

It is not necessary that the soil on which peanuts are to be grown should be naturally calcareous, but if it is not it must be limed, the lime being necessary both for the proper fruiting of the plant and for its mechanical effect upon the soil. Much of the Virginia and North Carolina land has in times past been heavily marled, and there are parts of Tennessee and other States where there is already sufficient lime in the soil for the peanut plant.

Besides this addition of lime on soils where it is not naturally found, the peanut needs a dressing of potash and phosphoric acid. The potash is best supplied in the form of kainit, the phosphoric acid by fine-ground phosphatic slag. If the soil is heavy, instead of the slag a dressing of superphosphate may be used.

The lime and other dressing would be more effective if plowed under early in the season, but they may be spread down the furrow in which the seed is planted or applied as a top-dressing after planting. Any kind of lime may be used, provided it is finely comminuted by burning before application. Thoroughly burnt oyster shells, which are very accessible to farmers living along the Eastern Seaboard, common limestone, or marl will answer the purpose of the planter.

The quantity of lime or marl to use at one application depends very much on the nature of the soil and the amount of vegetable matter it contains. Generally 30 bushels of lime or from 100 to 150 bushels of marl are safe applications, but if the soil is quite thin and contains but little vegetable mold, more than this at one time would be attended with risk. A safer plan is to make several small annual applications of lime and also of vegetable matter (manure, compost, wood's earth, etc.), continuing this until a sufficient amount of lime has been applied. Land will bear large quantities of marl with perfect safety if kept well stocked with some vegetable matter to subdue its caustic effects. But most of the best peanut soil is deficient in humus, and the planter should begin cautiously, using small quantities of lime until he has supplied the other deficiency.

The amounts of fertilizing constituents required by a crop of 60 bushels of peanuts is shown in the following table, calculated from data reported by the Tennessee Experiment Station:

Fertilizing constituents required by a crop of 60 bushels of peanuts.

	Pounds per acre.			
	Nitrogen.	Phosphoric acid.	Potash.	Lime
Peanuts with hulls (60 bushels or 1,380 pounds per acre)	44.22	9.08	12.73	4.66
Peanut hay (2,000 pounds per acre)	40.49	5.72	19.57	41.64
Total crop (3,380 pounds per acre)	84.71	14.80	32.30	46.30

It does not follow that these figures show the exact proportion of nitrogen, phosphoric acid, and potash, which a fertilizer for peanuts should contain. They are useful only as guides in calculating formulas for a fertilizer for this crop, and must not be followed too closely.

In the formulas given below the amounts of phosphoric acid and potash correspond approximately with those given in the last table, but nitrogen is reduced to one-fourth for the reason that the application of nitrogenous manures to leguminous plants does not make any appreciable return for the outlay, since they are able to obtain a large part of their nitrogen from the atmosphere. Each of the mixtures contains about 21 pounds of nitrogen, 15 pounds of phosphoric acid, and 32 pounds of potash in available forms, and will be sufficient for one acre.

Fertilizer mixtures for peanuts.

FORMULA I.

Cotton-seed meal	300 pounds.
Cotton-hull ashes	130 pounds.

FORMULA II.

Acid phosphate	80 pounds.
Cotton-seed meal	300 pounds.
Kainit	240 pounds.

FORMULA III.

Barnyard manure	2 tons.
Cotton-seed meal	150 pounds.
Kainit	100 pounds.
Acid phosphate	50 pounds.

FORMULA IV.

Acid phosphate	100 pounds.
Dried blood	185 pounds.
Muriate of potash	65 pounds.

When phosphatic slag, which generally appears in the American market under the name of Odorless Phosphate, can be obtained it may be substituted with advantage for acid phosphate at the rate of 120 pounds in Formula II, 75 pounds in Formula III, and 150 pounds in Formula IV.

Few of the peanut planters pay sufficient attention to the rotation of their crops, but year after year plant peanuts in the same land, or at best change from peanuts to corn and then to peanuts again, with the result that the land rapidly deteriorates. Not only does the crop of nuts become smaller and smaller, but the vines, after a year or two of this treatment, lose their leaves before maturity, and thus the hay or forage part of the crop is practically lost.

When the land is kept in a good physical condition by the use of lime and proper culture, and a systematic rotation of crops is followed, it will not only retain its fertility and produce good crops for many years, but it will constantly increase its ability to produce peanuts in paying quantities. A good rotation is soja beans or cowpeas, to be followed the succeeding year by peanuts, and the next year by sweet potatoes; or the following one, that will keep the land well covered and is perhaps more convenient for the average peanut planter, is recommended: Peanuts followed in the fall by winter rye or oats and the next summer the land sown to crimson clover, to be followed the succeeding year by peanuts again, so that every other year peanuts will be the crop. The advantage of this would be an increased forage crop for the farmer—a much-needed addition in the peanut-raising sections of the United States—the covering of the land during nearly the whole year with a growing crop and the rotation of a cereal with a leguminous crop. Even in this system of rotation fertilizers should be used, until the soil is brought into good condition and no longer responds profitably to fertilizers.

It should be clearly understood that constant cropping without the use of proper rotations or manures must eventually impoverish both the soil and the planter.

CULTURE.

Preparation of the land.—There is no mystery connected with the culture of the peanut crop or any special secret knowledge as to the preparation of the land. Any modes of preparation that will reduce the soil to a finely pulverized seed bed, light and friable to the depth of 4 or 5 inches, will be safe to adopt. Peanuts being planted usually after corn, it is necessary to remove from the soil the butts of the cornstalks, together with all other roots, clods, etc. The ordinary course followed by successful planters in various sections where peanuts are a prominent crop, is to break up the land with ordinary turn plow as soon in the spring as the soil is in condition to be worked, and then use a harrow and roller or smoothing board in such a way as to leave a level surface and seed bed, such as is above described, all roots, stumps, stones, and clods having been carefully removed.

Seed selection.—While there is among all planters a certain amount of selection of seeds for planting, more or less carefully done, according to the skill of the farmer and to the nature of the crop which he is about to plant, and in some cases extending to an elaborate and long-continued selection from the most prolific plants, yet in the case of peanuts, where good seed is of paramount importance, there seems to be but little more than ordinary care taken in the selection of seed—not more than in the saving of that portion of the crop which is to be sold on the market.

The seed should not only be carefully selected at the time of planting, carefully prepared so as not to break the skin of the kernel, and all immature, shriveled, or musty seeds rejected, but especial care should be exercised at the harvesting of the previous crop so that the seed may be of as great vitality as possible. The slightest frost upon the peanut vines either before digging or after they have been dug and before they become thoroughly dried will affect, to a greater or less degree, the vitality of the kernel. Overheating or mustiness is also detrimental to the kernel as a seed; consequently the seeds should be selected in the field before digging. They should be allowed to sun longer than peas intended for sale that they may be drier, and even should the pods lose color it does not matter, as the kernels will not be effected. They should be so stacked as to be kept very dry, and should be picked and allowed to dry thoroughly before being packed away for the winter. The best plan is to put them in bags in a cool, dry loft where they will neither heat nor collect moisture. Not more than two bushels should be placed in one sack, and great care should be taken to have the air circulate freely among them.

As it requires 2 bushels of nuts in the pod to give seed enough for an acre, and some farmers plant from 50 to 100 and even more acres, it is necessary to begin to shell the seed (nuts) several weeks before the time of planting. This requires some skill and care, both in opening the pod to avoid the breaking of the skin of the kernel and in selecting the sound and rejecting the imperfect kernels as they are shelled; and the seed thus shelled must be kept in a dry, cool, airy place until the time of planting.

Planting.—The time of planting depends upon the latitude, the distance from the sea, and the elevation of the section in which the seed is to be planted. In Virginia from May 1 to 20 is probably the time during which the larger part of the crop is planted, danger of killing frosts being past by that time, although some farmers plant the last week of April and others not until early in June. In more southern latitudes planting takes place in April, and farther north not before June. In no section should the seed be planted until all danger of the young plants being injured by a late frost is over.

As soon as the farmer has satisfied himself that the propitious time for planting has arrived, his land being in fine condition and his seed already prepared for planting, the question for him to decide is the distance between the hills which is best suited to the strength and fertility of his soil and to the variety of peanuts he intends to plant. As a part of this question he has to determine whether he will plant his seed in checks or in drills, both of which methods are in use in nearly every section where the peanut is grown. The advantages of one method over the other will depend upon the freedom of the soil from weed seed and upon the cost of labor. In checks, the cost of planting is probably greater than in drills, but if the ground is somewhat full of weed seeds the cost of cultivation in checks would probably be less than in drills, because of the ability of the horse implements to more successfully keep down the weeds, as the field can be worked in both directions very close to the young plants, leaving but little for the hoe to do.

The distance between the drills or hills is, as above stated, dependent upon the variety to be planted and the fertility of the soil. In very fertile soil and with the running Virginia nut from 3 to 3½ feet square each way is the required distance between the hills, with 2 kernels to the hill; while with other varieties or on less fertile land the distance between the hills can be reduced, until on poor land with the Spanish nut the distance will be determined by convenience in using horse implements between the rows.

In drills, the causes stated above would affect the choice of distance, that most frequently chosen by the planter being 3 feet between the drills and 14 inches between the hills down the drill, 2 seeds to the hill.

In checking the land for peas a simple and inexpensive marker is in common use for the first marking out of the field. This consists of a piece of scantling 4 by 4 inches and 6 or more feet long, through which are inserted, at distances equal to the required distance between the hills, wooden pegs 2 by 3 inches and 18 inches long, shod at the ends with iron. To the main bar are attached a pair of shafts and handles to be used in drawing and guiding the implement. The cross marking is usually performed with a small turn plow, the droppers following it putting 2 seeds to the hill, covering them over with the hoe, or probably more commonly the foot, to the depth of 1½ or 2 inches, although some cover the seed with a small plow.

There is in use among peanut farmers a planter planned somewhat after the manner of a cotton-seed planter. It is drawn by one horse, and is fitted with a "shoe," at the base of which the kernels are dropped at distances from 8 to 20 inches apart, according as the machine is geared, and are covered by a concave wheel, which, passing over the furrow, presses the soil firmly down upon the seed.

Tillage.—The object of all plant cultivation is to keep the soil in proper condition for the growth of the plant. An important means to that end is the destruction of all weeds. Many crops are injured by the lack of cultivation, more by improper cultivation, and some undoubtedly by too frequent cultivation. The maxim that "the best cultivation is that given before a crop is planted, and the next best the one that is not given it" at the latter part of its growth, is perhaps as true of peanuts as of any other crop. If the farmer has prepared his land, having it porous, pulverized, and free from all weed seeds, there will be need of very little cultivation. It is not so much a matter of how many times the crop has been worked as in what condition the crop is at any given time that should determine the farmer in his management of it.

The implements of cultivation are the plow, harrow or cultivator, and hoe, all of which are used by some farmers, others dispensing with one or two of them. Where the peanuts are planted in checks, the larger part of the cultivation is done with the harrow or cultivator, while some cultivate peanuts, even when in drills, solely with the aid of the turn plow. Hoe work being very expensive, the farmer should strive to have his land in such condition as not to require much of it, and to so cultivate his crop in its early stages as to prevent the growth of grass, necessitating the use of the hoe.

One method of weed destruction, as practiced by a large number of peanut planters is, just before the plants are coming through the ground, say two weeks after they have been planted, to go over the field with a small turn plow, throwing the soil from both sides over the drill or hill, or where the seed was first covered with a plow, throwing the second furrow over them, and then "blocking off" these ridges with light wooden scrapers or "blocks," thus destroying the first weed crop with very little or no injury to the peanut plants. Another method is to bar off the soil from the vines, throwing it into the balk, and then a few days afterwards to send the harrow and hoes through the field, leveling the ridge in the balk and scraping off the narrow ridge between the plants, as in cotton culture. After this use a double shovel every ten days or two weeks until the field has been gone over five or six times. For the first two or three plowings the shovels may be run deep, and after that very shallow, each working being a little farther from the plant than the preceding one, to avoid disturbing runners. The pods are laid by the middle of July or the first of August, and the cultivation is finished by the latter date. After the peas begin to spread it is difficult to clean them, and therefore they should be thoroughly cleaned while they are young.

Two methods of peanut culture in vogue may be distinguished as the "level" and the "ridge" methods. In level cultivation the turn plow has no place, but the work is done almost entirely with the cultivator, the field when laid by presenting a flat appearance much resembling a clover field. In the ridge method the soil is, by use of either the cultivator or the turn plow, gradually worked from the balk to the vine, so that after the last working the peanut field very much resembles a sweet potato patch. Which of these two methods is of greater merit is perhaps not definitely decided, or indeed which may be more advantageous upon certain soils and with certain varieties, although the level cultivated field will probably stand drought better than the ridged.

The Nebraska Experiment Station made an experiment on this subject. Eleven rows were drilled 3 feet apart and seeded 10 inches apart down the row. Every other row was ridged and the bloom was covered, while the alternate rows were left level. The 5 ridged rows yielded at the rate of 2,944 pounds to the acre, the 5 level rows at the rate of 5,368 pounds to the acre. This would seem to indicate level culture as best for the peanut, and certainly demonstrates that there is no need of following the old practice of covering the bloom of the plant. The eleventh row was planted with unshelled seed, ridged, the bloom covered, and yielded at the rate of 1,870 pounds.

HARVESTING.

The nuts should be out of the ground before the first frost, as it is injurious both to the vines, when regarded as fodder, and to the kernels. It may be necessary to dig the crop some time before frost is feared, because early formed nuts when frost is long delayed begin to sprout, and the loss to the farmer from that cause would be greater than the gain from the maturing of the later nuts. Besides, if peanuts have been cultivated in the same land for several years the vines often will drop their leaves and are thus greatly injured for use as hay.

Peanut farmers have a plow made especially for harvesting this crop, which has no moldboard and has a bar 3 feet long and an upright the same as the other plows. The foot piece is welded 12 inches from the rear end and extends up 5 inches, with a small hole through it, to which is fastened the hind helve of the plow. The beam is as usual, with handles fastened to either side of it. There is a duck bill on the flat end of the bar and a sword 4 inches wide and 16 inches long welded to the bar 5 inches behind the duck bill and extending out to the right side diagonally and backward, so as to run under and cut the taproot of the vine.

This plow, with two horses attached, is passed up each side of the row deep enough to escape the peas, the long wing cutting the taproots, rendering them easy to remove from the soil. Following this plow laborers with pitchforks remove the plants from the ground, carefully shaking off all loose soil, and piling then in windrows three rows in one. They are usually plowed in the morning, and then in the afternoon are stacked or shocked around poles 7 feet high, set in the ground at convenient places in the field. In shocking, care is taken to keep the vines from the ground, the usual practice being to lay a couple of fence logs on each side of the center pole, and the plants are so arranged around the pole as to have the pods inside, and also to leave some space next to the pole for the circulation of air. The shocks are usually capped with corn fodder or hay to keep out the rain.

After being thus stacked from fifteen to twenty days the pods are ready to be picked. This operation is usually performed by women and children, who are paid so much per bushel, and are expected to pick only the mature and sound pods. It is slow and tedious work, and one of the largest items of expense to the peanut farmer. Some farmers leave their nuts unpicked until spring, but this subjects them to the depredations of birds and animals, many of which readily eat either the nuts or the vines.

In the Wilmington section there is some variation from the above in the method of harvesting the crop. The vines after being allowed to remain in the ground two days after plowing are then pulled out and shaken free from soil and stacked around poles 12 to 14 feet high, where they are allowed to remain about a week or ten days and are then removed to large barns and stored away like clover hay until it is convenient for the planter to have his nuts picked. This peanut being much smaller than the Virginia or Tennessee nut and also more completely filling the shell, is not so easily injured as the larger varieties, and thus can be picked by machinery of the general nature of a thrashing machine. Some dealers object to machine-picked nuts, but the experience of those who follow that practice in harvesting their crops shows but little if any difference in the price of hand or machine detached pods of the North Carolina variety, and what difference there may be in price is offset by the saving in cost and the rapidity with which they can be put upon the market at any desired time. Besides, it is claimed that the hay, after passing through the picker or thrashing machine, is in better condition for fodder than the hay from the hand-gathered peanuts.

After the peanuts are picked they should be cleaned before being sacked. The necessity of cleaning is of course not so great as it was prior to the establishment of recleaners or factories, but still the cleaning of the nut would not only leave a large number of pops and saps on the farm for the feeding of stock, but would doubtless cause the nuts to bring a price sufficient to justify the expense of cleaning. The sacks used for peanuts are either 66 or 72 inches long, and wide enough to hold 4 bushels, or 100 pounds. Even should the farmer not intend to sell his nuts at once, he should at least sack them, as an attempt to keep them in bulk might cause them to heat. In filling the sacks care must be taken to fill each corner, and the entire sack should be well distended, yet not tight enough to crush the shells. Put away in a dry, airy place, peanuts will keep in these sacks several years, should it be necessary so to do.

Yield.—According to the Eleventh Census (Bulletin No. 378, p. 9), the average yield of peanuts in the United States in 1889 was 17.6 bushels per acre, the average in Virginia being about 20 and in Tennessee 32 bushels per acre. This appears to be a very low average, especially as official and semiofficial figures give 50 or 60 bushels as an average crop, and 100 bushels is not an uncommon yield. Fair peanut land properly manured and treated to intelligent rotation of crops should produce in an ordinary season a yield of 50 bushels to the acre and from 1 to 2 tons of excellent hay. Of course better land with more liberal treatment and a favorable season will produce heavier crops, the reverse being true of lands which have been frequently planted with peanuts without either manuring or rotation of crops. Besides the amount of peas gathered there are always large quantities left in the ground which have escaped the gathering, and on these the planter turns his herd of hogs, so that there is no waste of any part of the plant.

The yearly production of peanuts in this country is about 4,000,000 bushels of 22 pounds, Virginia, Georgia, Tennessee, and North Carolina being, according to the Eleventh Census, the largest producers in the order named. These 4,000,000 bushels, while fully supplying the present demand in the United States, constitute but a small portion of the peanut crop of the world, as the exportation from Africa and India to Europe in 1892 amounted to nearly 400,000,000 pounds, Marseilles taking 222,000,000 pounds, most of which were converted into oil. The peanut crop of the world may be safely estimated as at least 600,000,000 pounds.

Preparation for market.—Since the establishment of peanut factories, or "recleaners," in nearly every community in which much attention is paid to this crop, the planter has ceased to especially prepare his nuts for market, selling them as "farmers' stock" to those factories or recleaners, where they are subjected to a treatment of fanning, polishing, and sorting before being put upon the market. This process is simple and inexpensive.

The machinery, neither costly nor intricate, is placed in a four-story building in such a way that the peanuts are not handled from the time they are put in their uncleaned condition in the hoppers on the fourth floor until on the first floor they are sewed in bags, branded, and marked ready to ship, with the exception that in the course of this process they have passed over a movable table in the form of an endless belt, between two rows of operators somewhat skilled in the detection of immature and faulty nuts, which are picked out and put into a separate receptacle, only the good and merchantable nuts being allowed to pass into the bag beneath; these are the hand-picked "factory stock" of the trade.

USES.

In describing the uses of peanuts it is scarcely necessary to more than refer to that use to which fully three-fourths of the American-raised crop is devoted. The nut is sorted in the factory into four grades, the first, second, and third being sold to venders of the roasted peanut, either directly or through jobbing houses. The fourth grade, after passing through a seller, is sold to confectioners, to be used in the making of "burnt almonds," peanut candy, and cheaper grades of chocolates. The extent of the use of the peanut by the American people will be more fully appreciated when it is remembered that they use 4,000,000 bushels of nuts yearly (at a cost to the consumers of $10,000,000), which do not form a part of the regular articles of food, but are eaten at odd times.

The nut is used by the planter as a fattener for his hogs, and reference to the analyses of the plant (table, p. 5) will at once indicate its value for that purpose. The planter also makes use of the vine under the name of peanut hay, which is carefully saved and fed to all kinds of live stock, furnishing the best and cheapest hay to be found in the peanut section. The chief objection to it is that it is apt to contain considerable dirt, which may produce coughs in the animals eating it. It should therefore be fed from low troughs or mangers, and never from racks overhead. If frosted it may cause colic, but well-cured hay will not do this. If many immature pods are left on the vines, stock that is not worked much would need no other food during the winter. Care must be exercised, however, when beginning to feed it to horses, as there is danger of the saps or immature pods left on the vines foundering them if too much is fed at once. An analysis of this hay, as compared with hay from clover, timothy, cowpea, and alfalfa, is found in the following table, taken from Bulletin Volume IV No. 2, of the Tennessee Experiment Station:

Feeding value of peanut hay as compared with hay of other crops.

	Moisture.	Dry matter.				
		Protein.	Fats.	Carbohydrates.	Crude fiber.	Crude ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent*	*Per cent.*
Peanut hay	7.83	11.75	1.84	46.95	22.11	17 04
Peanut vine	6.25	13.48	15.06	36.28	29.16	6.02
Clover hay	14.30	12.84	2.11	48.31	29.27	7.47
Timothy hay	13.50	7.17	1.97	52.94	33.41	4.51
Cowpea hay	10.29	19.72	4.04	45.15	21.99	9.10
Alfalfa	6.95	16.48	2.03	42.62	31.38	7.49

These analyses show peanut vines to be of high feeding value, comparing favorably in this respect with the most highly esteemed forage plants. When some of the nuts are cured and fed with the hay the feeding value is greatly increased, as the second analysis in this table shows.

These are uses to which the peanut crop is commonly put in this country, but it is not improbable that in the course of time the peanut may subserve other valuable ends here. Millions of bushels are being used in the countries of the Old World for the production of oil, in which the nuts are very rich. This oil is regarded as equal to olive oil, and may be employed for every purpose to which that is applied. This oil forms from 30 to 50 per cent (by weight) of the shelled nut; it has an agreeable taste and smell, and is more limpid than olive oil, which it very much resembles. Examinations of peanut oil manufactured in Tennessee show it to be very similar in character to cotton-seed oil and olive oil. It is sweet, palatable, and clear, and in fact great quantities are used, unknown to the consumer, instead of olive oil. To quote Consul Thomas, of Marseilles, in a report to the Department of State:

> Much of it is used for eating purposes, both as a salad oil and in the composition of margarin. When made from a superior class of nuts, not too finely ground, the oil is said to be of fairly good flavor, and in the case of dearth of olives, might

serve as an excellent substitute for the more popular though possibly not more widely consumed extraction. Indeed, the people of all others best able to give an expert opinion as to the merits of peanut oil for table purposes, and who annually consume considerable quantities under the name of, and perhaps too faintly diluted with, olive oil, reside in the United States.

In India, Europe, Brazil, and this country it is used medicinally in the place of olive oil, and it is also employed by manufacturers as a substitute for the latter in fulling cloth. As a lighting fluid it lasts a long time, but does not give as clear a light as other burning oils. It is a durable, nondrying oil of a light straw color, and it is for its oil that the nut is imported into Europe, many gallons being used in the manufacture of soap and as a lubricant in machine shops.

Consul-General Mason, of Frankfort, says:

> Cold-pressed oil of the first pressing of African or the best American peanuts is used in Germany as salad oil and for various culinary purposes. It ranges in price (wholesale) from $14.75 to $26 per 100 kilograms (220 pounds), or approximately from 56 cents to $1 per gallon, which is far cheaper than any edible quality of olive oil that can be imported and sold in that country. The American peanut is larger, sweeter, and, when roasted, better flavored than any of the others, but its oil is of medium quality and ranks below the African, being worth about $15.50 per 100 kilograms, or 59 cents per gallon.

A practical treatise on animal and vegetable fats and oils, by W. T. Brannt (London, 1888), says:

> The kernels yield from 38 to 45 per cent of oil. The first cold pressure yields 16 to 18 per cent of very fine table oil. The residue is then broken up, moistened with water, and again cold pressed, yielding 7 to 8 per cent more or less valuable oil used for table purposes and burning; the residue from this is heated and then pressed, giving 7 to 8 per cent more of oil unfit for table use, but used for soap and lubricating.

United States Consul Trail, at Marseilles, in a report on manufactures of vegetable oils, dated April 4, 1892, says, regarding the process in that city:

> These nuts are subjected to two pressings, the seed first being triturated and then heated to between 70° and 80° C. The yield of oil from the first pressing is about 50 per cent of the seed crushed.

Whether oil extraction from peanuts will ever become an established industry in this country depends upon (1) whether sufficient quantities can be secured to keep the mills at work, and (2) whether peanuts can be raised at a price low enough to compete with the other oil seeds which already have control of this market. To the average peanut planter, who for the past few years has been told that the market is overstocked and the supply greater than the demand, the intimation that the supply is not large enough for almost any purpose would meet with small credence; but a moment's reflection and calculation of the amount of nuts necessary to supply the demands of a first-class oil mill would at once show how comparatively small is the average crop. At 50 tons per day, 300 tons a week, or 15,000 tons a year, as a requisite amount to supply one mill, we find that nearly the whole American crop would be consumed by two mills. But under present conditions the mills could not pay the price demanded for primes or extra fine stock, therefore the part of the present crop which could be utilized in oil making would be limited to the amount of the third or fourth class stock produced, which would not supply one mill six months.

The question of prices is one which can be answered only by future improvement in the methods of culture, an increased production per acre, and the invention of more economical means of harvesting and handling the crop.

The most important secondary product of peanut-oil manufacture is the oil cake, or meal, which remains after the oil has been extracted by pressure. This sells for from $30 to $33 per ton in Germany, where it is used for feeding cattle and sheep. After all the oil which can be expressed has been secured there still remains considerable fatty matter in the cake, which, together with its other contents, makes a most valuable animal food.

An average of over 2,000 analyses collated by German authorities is shown on page 5. A recent analysis[1] of peanut cake furnished by an oil factory in Tennessee gave the following results: Water, 6.58 per cent; ash, 4.21 per cent; protein, 53.19 per cent; fiber, 3.75 per cent; nitrogen-free extract, 24.01 per cent, and fat, 53.19 per cent. This shows a nutritive value for the American product somewhat superior to the German average.

Dietrich and König give the average coefficient of digestibility of this cake as follows: Protein, 90.24; fats, 85.66; nitrogen-free extract, 92.87.

An experiment was made at the Woburn Experimental Farm, in England, to compare peanut cake at $40.72 a ton with bean meal at $45.80, for steers. Each was fed in a grain ration with equal parts of oats and barley, and the animals received besides 45 pounds of roots and 15 pounds of clover-hay chaff per head. The trial lasted 107 days. The peanut cake proved to be a useful feeding material for cattle and to have a feeding value just about equal to that of beans.[2]

Dr. W. R. Robertson[3] in his experiments with peanut cake as a food for horses at the India farm, of which he was manager, found that 6 pounds of cake per day was sufficient to keep a horse in good working condition, and describes the method of feeding thus:

> The cake was broken into small pieces and steeped for twenty-four hours in cold water, just sufficient to make a stiffish paste. This paste is white and has a rather agreeable nut-like smell and taste; it is readily eaten by most horses.

In reference to its use as feed for other animals, Dr. Robertson says:

> I have used the cake very extensively in feeding working cattle; an allowance of 4 pounds per head per day, with forage, kept the animals in perfect health and con-

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[1] Analysis made by the chemist of the Department of Agriculture.

[2] Royal Agricultural Society of England, No. 3, 1892, ser. 3, pp. 727–730.

[3] Jour. Roy. Agr. Soc. Eng., Vol. IV, Part III, 1893, p. 650.

dition. For fattening cattle I do not know of any better food, in regard alike to its feeding value and to the superior quality of the beef produced.

As a food for dairy cows it is admirable, both in increasing the yield of milk and in improving its quality. The butter of cows so fed is firmer and keeps much better than that of cows fed on any of the ordinary oil cakes. A daily allowance of 4 to 6 pounds of the cake, given in the form of paste, and mixed with 2 or 3 pounds of wheat bran, constitutes a perfect food for milch cows. I have had cows so fed for several years, yielding well and breeding regularly. For sheep there is no better food than earthnut cake, but for these animals I found it best to give the cake dry and broken into small pieces. I had a large flock fed on the cake for several years, and never knew any bad results attending its use. The ewes so fed bred regularly, milked well, and reared excellent lambs, while the mutton of these cake-fed sheep was of superior quality.

Many experiments have proved the value of the cake as a feed for pigs. For these animals it was usually made into a thin gruel and given mixed with bran. The same preparation, but in not quite so thin a condition, constitutes a superior food for fattening poultry. The flesh of poultry fatted on the cake is white, fine, and of superior quality.

From the above, and as a result of the various analyses, it can be concluded with certainty that the peanut cake is an excellent cattle food and can be made extremely valuable if judiciously mixed with other foods less rich in oil and nitrogenous constituents.

A grade of food for animals known as "peanut meal" is made by grinding the hulls, immature peanuts, and those of inferior grades, such as pops and saps, and a certain proportion of sound nuts mixed with other ingredients. This is carefully prepared, having all the dirt and foreign matter eliminated. The fiber is also to a large extent extracted, as well as the fluffy matter, and the meal is probably in a favorable condition for stock. The composition compares favorably with that of many foods now on the market. There is nothing in this preparation which can not be secured by the farmer himself without any expense, if he will take ordinary care in separating his marketable peas from the refuse stock before selling, which latter would be a valuable addition to the somewhat meager supply of winter fodder ordinarily provided by the farmers in the South for stock other than their work animals.

Although the experiment made with peanut meal and biscuits as food for the German army was not so successful as to induce the authorities to adopt it as a part of the rations, still analysis has shown conclusively that it is a most nourishing food for man, and as compared with other well-known forms of vegetable and animal food it has a high nutritive value.

During the years between 1861 and 1865, peanut oil was manufactured by at least four mills in the Southern States, and used as a lubricant by railroads for locomotives, by wool and cotton spinners for their spindles, and by housewives instead of lard as shortening in bread and pastry. The cake was eaten by many living in the vicinity of the mills, and was very highly spoken of by those who used it, as a palatable and nutritious food for man.

The following is a comparison made by Professor König, based on the price in Germany of the following twelve principal foods reduced to "units of nutrition:"

Comparison of the nutritive value and cost of twelve principal foods.

	Nutritive units per pound.	Cost per 1,000 units in cents.
Skim milk	98.2	10.4
Skim-milk cheese	870.0	11.0
Full milk	145.5	11.5
Bacon	1,257.7	15.5
Butter	1,186.3	20.4
Veal	525.9	22.2
Beef	530.9	26.0
Peas	778.6	4.2
Potatoes	138.2	5.1
Rye flour	603.6	6.0
Rice	534.6	10.0
Peanut meal	1,425.0	3.0

It follows, therefore, that peanut meal is not only the most nutritious, but by far the cheapest of this whole list of food materials.

SUMMARY.

(1) The peanut is a native of Brazil, but early after the discovery of that country it was introduced into Africa and other tropical parts of the Old World, where it became a staple article of food. It was only in the second half of this century that it became an important crop in this country.

(2) The varieties grown are the Virginia, running and bunch; the Tennessee and Georgia, white and red; the North Carolina, and the Spanish. The Virginia varieties, being most widely known and popular with the trade, are the ones commonly planted. There is little difference between the Virginia and Tennessee nuts, both being sold as "Virginia hand-picked" peanuts.

The Spanish nut has a small kernel of fine quality, and is in demand as "confectioners' stock," being worth several cents per pound more than any other shelled stock.

(3) The climate of the Atlantic Seaboard and Mississippi Valley has proven very congenial to this plant, which needs an early and warm spring, followed by a hot and moist summer, with but little rain in the harvesting season to injure the mature crop.

(4) While an open sandy soil which does not stain the shell is the ideal one for the peanut, it thrives on any friable soil that contains a sufficient quantity of lime and humus. The presence of lime is necessary for the development of the nuts, as without lime there may be luxuriant vines bearing nothing but pops. If the soil does not already contain lime in sufficient quantities the deficiency must be supplied by the use of some form of commercial lime, such as burnt oyster shells, burnt limestone, or marl.

(5) The peanut plant draws a large part of its nitrogen from the air, but it draws a considerable amount of phosphoric acid and potash from the soil. If the entire plant is removed from the soil, the crop becomes an exhausting one, and the fertility of the soil must be restored by the use of manures and rotation of crops.

(6) Peanuts should be planted in well-pulverized soil to a depth of 4 inches. The distance between the rows should be from 28 to 36 inches, varying with the fertility of the soil and the variety. Fertilizers should be applied broadcast before planting, but they may be applied in the rows, and at the time of planting. Carefully shelled and selected kernels should be used for seed. The seeds should be planted from 12 to 20 inches apart, two to the hill, and covered about an inch deep, either with a hoe or a small turn plow. All grass and weeds must be kept out of the field, and the soil kept loose and open, that the tender "spikes" may meet with no resistance in penetrating the ground. Experiment has not shown any definite results favoring either the ridge or level culture, and the nature of the field selected for the crop will be the best guide as to the method to be adopted. The crop should be laid by in July, or as soon as the vines have spread sufficiently to keep down the weeds, or to make the passage of the harrow between the rows dangerous to the developing pods.

(7) In harvesting the crop, the practice is to pass down each side of the row with a plow, made especially for the purpose, without a moldboard, and with a "sword," or long cutting flanges welded to the point. The plow is run deep enough to sever the taproot, without disturbing the pods. The vines are then lifted from the ground with pitchforks, and placed in rows; they are afterwards stacked around short poles. Two weeks later the pods should be dry enough to be picked off. After picking the nuts are placed in bags, holding 4 bushels, and either stored away in dry, well-ventilated sheds, or at once sold to the "factories," where they are cleaned, sorted, sacked, and branded. They are then ready for the trade.

(8) The larger portion of the American crop is sold by street venders, but small amounts are used by confectioners, chocolate manufacturers, and for the manufacture of oil. Peanut oil is used for lubricating and soap making, and is a good substitute for olive oil for salads and other culinary purposes, and as a substitute for lard and cottolene and butter in cooking. The residue from oil making, known as "peanut cake," is a highly valued cattle food in the countries of Europe, and is also ground into fine flour and used as human food. It makes good soup, griddle cakes, muffins, etc., and is one of the most nutritive of foods. It has, however, not been sufficiently tested to make it certain that it will be useful as a regular article of diet. The vines when dried become a very nutritive hay, readily eaten by stock; but in feeding care must be taken lest it give them colic.

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